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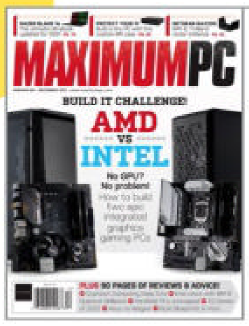

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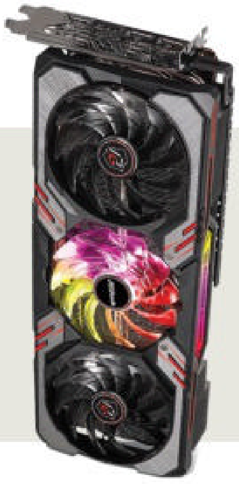

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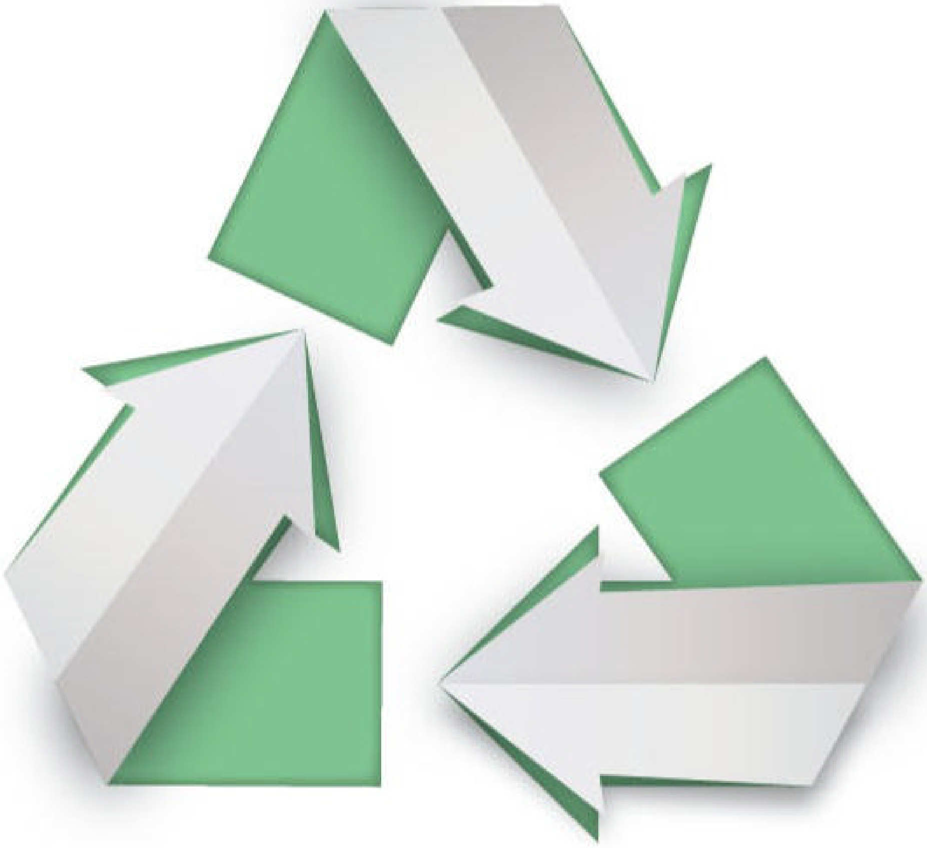

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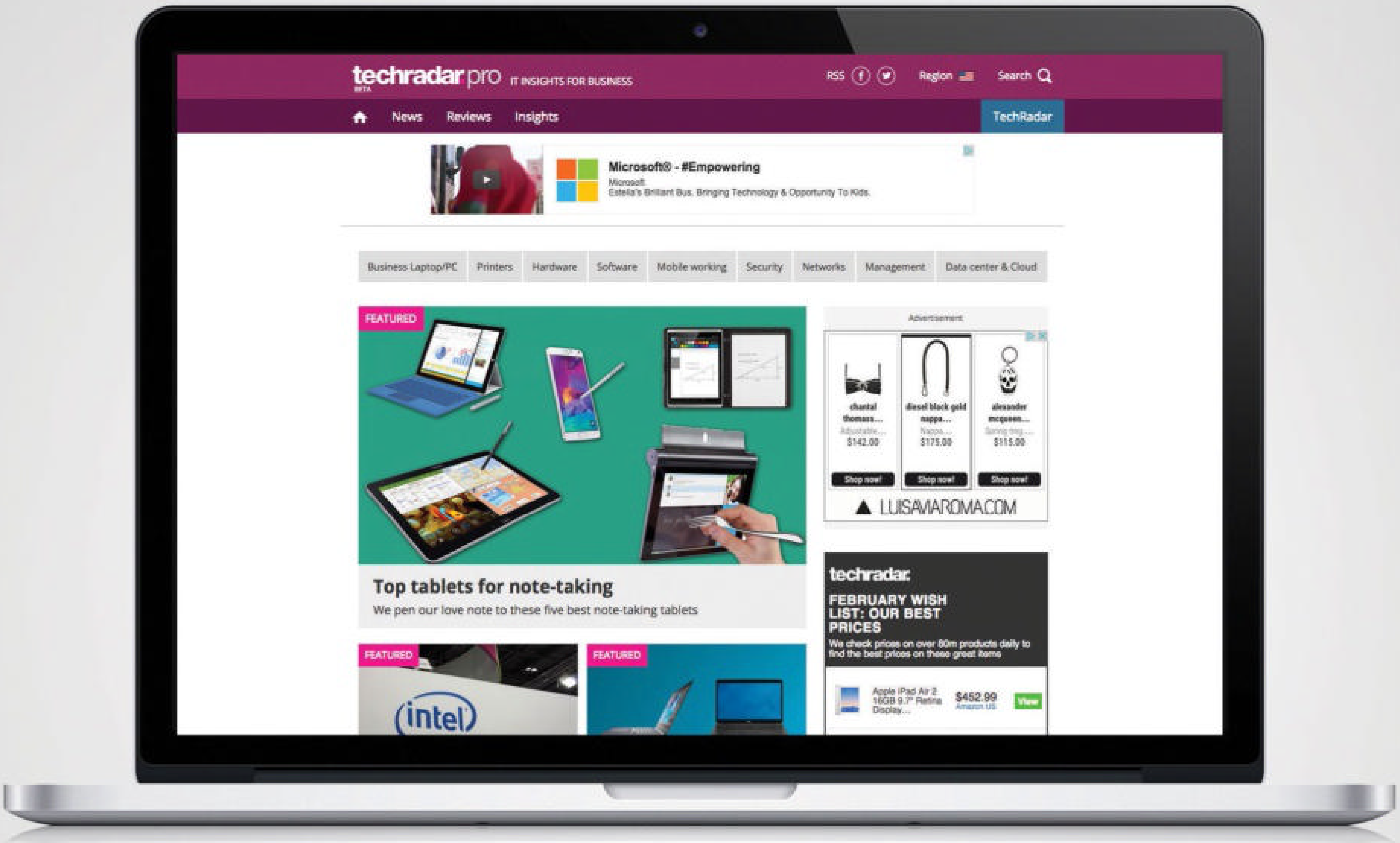

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QUANTUM LEAP

IT'S BEEN a heck of a month for myself and the team at *Maximum PC*. There's been a lot going on in the background, and the next few issues look seriously awesome from a content perspective. Honestly, some of the features we've got lined up are going to be epic! From Ian's long-form excellence to Nick's software-based goodness, it's all go. On top of that, we're expecting new processor launches too (which always makes us happy fellas). AMD is, without a doubt, king of the hill right now when it comes to CPU performance, but with Intel about to debut its next-gen chips, could this be the moment Team Blue takes back the multi-core crown? We're not so sure, only time will tell.

With that notion wedged firmly in our minds, we decided it was time to pit those two CPU rivals against one another, once more, in a truly epic battle of the builds. This time though, it was a build-off with a twist. Traditionally, we've always had these two go head-to-head in a high-end professional enthusiast competition, seeing which is the better platform to build your next workstation on. But, given the way the GPU market is nowadays, that just didn't seem right, and so, with AMD's most recent launch of its latest Radeon powered APUs making waves, we decided it was time to see which team could give us the best integrated graphics performance at 1080p when no holds were barred.

Sam and I set out to build two sub-$1000 builds to pit the might of AMD's Radeon iGPU against Intel's UHD750 graphics in a true test of budget gaming. How far have we come? Is it possible to game on these things? Head over to page 18 and check it out, we've also got detailed guides to building both machines on page 68 too, which is well worth a look if you're considering building a budget machine of your own.

For our other main features this month, Ian's written a fantastic article (or he might not have, you won't know until you check) on the state of Quantum Computing. What is it? How does it work? What can it do? And where are we heading with it? All on page 28. And yes, I did make a terrible Schrödinger's cat pun there, don't hate me. Our resident retro guru from down under has given us an in-depth history of ultra-mobile PCs (before smartphones ruined everything), and Christian compiled a list of 22 games to look out for in 2022.

On top of that, we've got a set of epic reviews as well, from Corsair's first monitor to the new Razer Blade 14 laptop, the ASRock RX 6700 XT GPU, a fancy new Lian Li case, and even some networking goodness from Netgear too.

Lastly, our Centerfold piece this issue is a bit different. Our resident freelance writer and PC modder, Kris Butterill, has built one heck of a rig for Intel, that you can potentially win. This isn't content that Intel has paid for, and the charity sweepstakes are being run by Intel as well (see details on page 46), we just thought it was a cool-looking rig. Kris is going to be showing us what it's like being a PC modder in a fantastic feature lined up for the next issue too.

With columns, news, blueprints, and more, this has been a heck of an issue to put together, and one I truly hope you enjoy. Until next time!

Zak Storey

Zak is Maximum PC's *editor-in-chief and long-time staff member. He's been building PCs since he was 10, and is more than capable of butting heads with the biggest names in tech.*

↘ submit your questions to: editor@maximumpc.com

THE NEWS

Facebook's Dark Side

Time to take some responsibility

BY ANY MEASURE, Facebook is a picture of success. From small beginnings in 2004, it has grown into a company with a market capitalization of around $900bn. There are nearly 2.9 billion users worldwide, with an estimated 70 percent of all Americans having an account. On top of this, you can add a billion Instagram accounts. Success inevitably brings detractors, but Facebook is under fire, and its ex-employees are providing some of the best ammunition.

A Facebook data engineer, and whistle-blower, Frances Haugen, leaked thousands of internal documents that highlight the problems and went on to testify to the US Congress. "The thing I saw at Facebook over and over again were conflicts of interest between what was good for the public and what was good for Facebook," said Haugen. "Facebook, over and over again, chose to optimize for its own interests, like making more money".

Haugen claims Facebook puts engagement above all else, in whatever form that takes. Despite publicly condemning hate speech, internal documents reveal that under 5 percent is removed, and less than one percent of incitements to violence. Meanwhile, since outrage often triggers a response, the algorithms simply serve up more outrage. A Civic Integrity unit was supposed to keep this in check, but that was disbanded last year.

An internal report from 2019 highlights the problem of troll homes: pages with no meaningful connection with their purported field, but that merely exist to channel propaganda, marketing, and click-bait junk. They are so effective because Facebook's feed ranking algorithms push them forward. Facebook promised to fix this in 2016, but its lack of action prompted the report's author to leave Facebook and release it online.

Facebook's attitude to children is a particularly hot topic. Legally, you have to be 13 to open an account, but efforts to enforce this are minimal. Another recent report revealed that 40 percent of children under 13 use Instagram, and half use Facebook, half of these used an adult to open the account. Facebook even planned a version of Instagram aimed at 'tweens'. These plans were shelved when they became public, after protests from all sides. Instagram's head said, "we want to take time to speak with parents and experts working out how to get this right". As the National Center on Sexual Exploitation put it; "this was an irresponsible idea from inception".

> Social media is akin to a vast experiment being run on a whole generation

Facebook commissioned a report on social media's effects on the mental health of teenagers. Diminished body image was reported by about a third of teenage girls, whilst between 6 and 13 percent traced their suicidal thoughts back to Instagram. Once again, the algorithms amplify the problem, showering users with an endless array of heavily filtered images, whilst the infinite scroll feature adds a never-ending parade of comparisons. Despite the findings, little action was taken to rectify this.

You cannot argue for ignorance here, the big tech guys know that the early use of technology, and social media, in particular, isn't a good idea. Steve Jobs didn't let his kids have an iPad when it was released, Bill Gates kept the technology in his home to a minimum, capped screen time for his children, and didn't allow them a smartphone until they were 14. Zuckerburg wrote a letter to his second child urging her to go outside, and play and "smell the flowers" while she is young.

It is easy to knock Facebook, and, to be fair, it had no idea just how big it would get or how strong its influence would be. Social media is akin to a vast sociological experiment being run on a whole generation, and the results aren't always pretty. We are being a little unfair here, social media isn't inherently bad for children or society, but too much, too soon, too young, and badly monitored can be.

There is nothing new in this knowledge, but now we have a wealth of internal research that proves Facebook is well aware of the problems. So what next? Facebook is powerful enough to ride this out. Its stock price dipped, but even the $6bn loss won't touch it. The only real danger is legislation, and that's unlikely on any scale anytime soon. As Uncle Ben tells a young Peter in *Spider-Man*: with great power comes great responsibility. Facebook has great power, but the responsibility appears to be severely lacking. **–CL**

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CHINA BANS CRYPTO

THIS TIME, IT MEANS BUSINESS

AFTER THE RESTRICTIONS IMPOSED on cryptocurrency mining this summer, the Chinese government has declared that all transactions of such currencies are illegal. This isn't a new thing. Virtual currencies were first 'banned' in 2009. Bitcoin transactions by banks were banned in 2013. In 2017, there were bans on exchanges. In total, there have been 19 attempts to stifle the market, but each time, it seems to thrive. This time, all citizens trading in coins are involved in illegal financial activity; the law singles out overseas exchanges providing services within China. One exemption is the digital Yuan (e-CYU) cryptocurrency, which is under government control. The fact the process chews through a lot of electricity doesn't help, given the current shortages. Has this caused Bitcoin to plummet? No, it merely wobbled and bounced back. China's mining boom is over and the big players have started moving abroad. Texas currently has some of the world's cheapest electricity and is a popular new home for miners. **–CL**

THE EMPIRE STRIKES BACK

Intel's hybrid technology reaches the desktop

AS WE WRITE, the official launch of Intel's Alder Lake-S chips is within sight. Alder Lake is a 12th-generation chip employing a new LGA 1700 socket, so new boards are required. It's a hybrid architecture, mixing Golden Cove cores for power, and Gracemont cores for efficiency. Each Golden Cove core gets 1.25MB of L2 cache and there's up to 30MB of shared L3 cache, DDR5 support, and PCIe 5.0 lanes. Next year, it will reach laptops, with the Alder Lake-P series, followed by the Alder Lake-M for ultra-low power devices.

The top-of-the-range chip is the Core i9-12900K, with eight cores and 16 threads. It is fast—a test using *Ashes of Singularity* gave the blue team around a 20 percent lead over AMD's Ryzen 9 5900X—and Intel has released a desktop processor to ruffle AMD's feathers. Intel's CEO, Pat Gelsinger, claims that Alder Lake marks the end of AMD's dominance in the performance processor market. We are preparing to be suitably impressed.

AMD knew this was coming, and before we get to Zen 4 there will be the Zen 3 V-Cache, essentially using a chip-stacking process to slap 64MB of L3 cache on top of the processor cores, giving an expected performance bump of 15 to 20 percent. The launch date looks unlikely before the new year, but next month, we'll see if Intel has earned the desktop gaming crown back. **–CL**

Tech Triumphs and Tragedies

A monthly snapshot of what's good and bad in tech

TRIUMPHS

✓ **HUMBLE BUNDLE**
The game-selling firm gives a percentage to charity and has now passed the $200m mark.

✓ **A NEW PLANET?**
After losing Pluto, simulations of the creation of the solar system indicate we may have a Mars-sized planet out there in the cold.

✓ **OLD SCHOOL DEATH**
Quake inspired a generation of FPS games and it has now been remastered with 4K resolution and greatly updated graphics.

TRAGEDIES

✗ **BAD MEMORIES**
Chia miners in China are dumping their SSD drives onto the used market. Avoid.

✗ **FACEBOOK SNAFU**
After a software update to its Border Gateway Protocol, Facebook's empire shut down, including the doors at its HQ.

✗ **BLANK WINDOWS**
Just before the Win11 launch, a report found that 62 percent of Windows users were unaware that a new version even existed.

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SMOOTH OPERATIONS

Nvidia has a new anti-aliasing system

ELDER SCROLLS Online, which was originally launched in 2014, will be the first game to benefit from Nvidia's latest piece of wizardry: Deep Learning Anti-Aliasing (DLAA). It's a development of the existing DLSS (Deep Learning Super Scaling) system. At its most basic, DLAA is DLSS without the upscaling, instead, the AI concentrates entirely on anti-aliasing. It employs the Tensor cores found in Nvidia's RTX 2000, and 3000 series graphics cards, so you'll need one of those.

There are various ways to remove the jaggles, all cost processing power, and hence frame rates. One method is Temporal Anti-Aliasing (TAA), which combines pixel data from previous frames with the current frame. It works well but doesn't always handle motion effectively, leading to a ghosting or smearing effect. DLAA uses AI to track motion, lighting changes, and sharp edges to produce a cleaner image, and minimize any ghosting.

While DLSS offers higher resolutions with minimal performance loss, DLAA does the opposite, with better image quality at native resolutions, but incurring a performance loss. It works well with older games that can be comfortably run at high frame rates with processing power to spare—switch on DLAA and it can be used to bump up the image quality. Since it is based on existing DLSS technology, DLAA should be easy to implement on any game with DLSS support, offering another graphics option to play with. **–CL**

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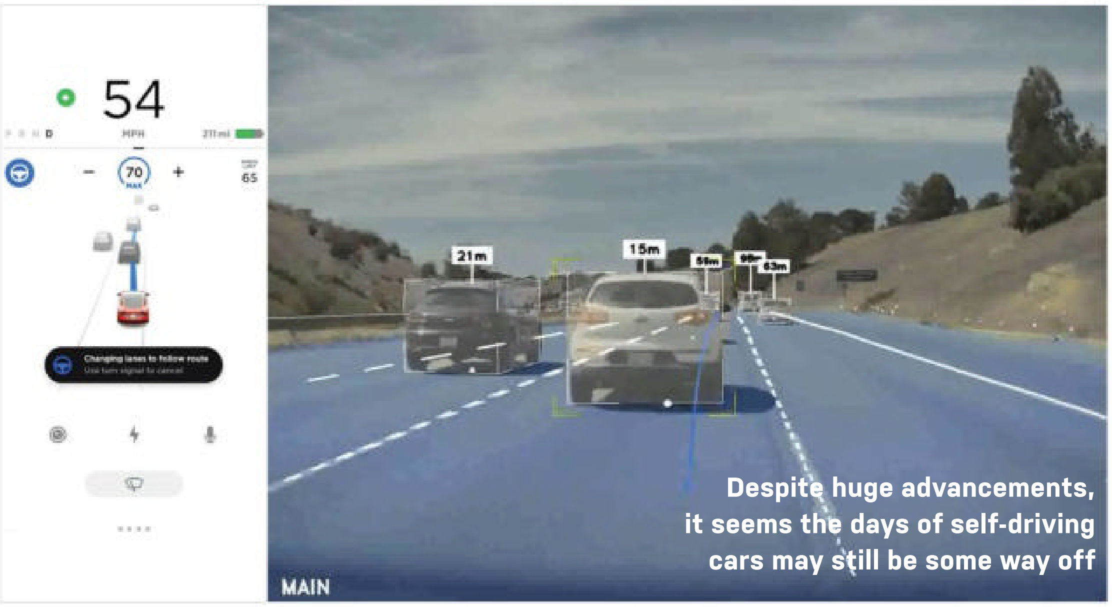
PC GAMER

Tesla goes almost self-driving

TESLA HAS LAUNCHED a beta version of what it terms Full Self-Driving (FSD)—not technically fully autonomous driving, but close. You'll still need to sit in the driver's seat and prove you are a safe driver, with Tesla examining your driving record for examples of hard turning or braking, and collision warnings. Meanwhile, the National Transportation Safety Board and the National Highway Traffic Safety Administration are busy investigating a number of Tesla crashes. The NTSB has called the name Full Self-Driving "misleading and irresponsible", since it certainly isn't 'Full'.

Accidents with self-driving cars are over reported, but there has been an issue with cars plowing into emergency vehicles under Autopilot. A big part of the problem is a false sense of security from the drivers. A recent report from MIT confirmed that with self-driving mode engaged, people don't pay attention. It's why experts advocate jumping from assisted modes to fully autonomous, avoiding the intermediate steps.

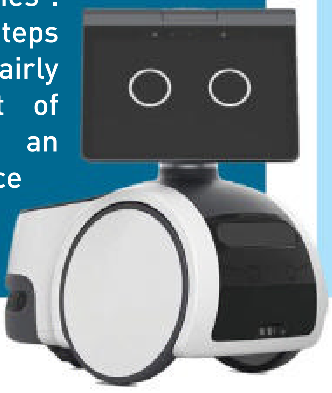
Self-driving vehicles have attracted billions of dollars of investment from major car manufacturers and tech companies. But over the past few years, expectations have cooled and, despite what Elon Musk says, fully autonomous driving remains a massive technical hurdle. The human world is complicated and fully autonomous vehicles remain practical only in specific environments. Meanwhile, the first fully autonomous, and crewless, cargo ship is due to set sail later this year. **–CL**



Despite huge advancements, it seems the days of self-driving cars may still be some way off

Amazon's Robot

Amazon has built a household robot: Astro. This 20.6lb device, which resembles a screen on top of a small vacuum cleaner, 'learns' the layout of your home and can navigate independently. There is a camera on an extendable mast and it can follow you about, which is fun for video calls. You can also operate it remotely to look around your home while you're out. Amazon's promotional blurb struggles to explain why you might want one, suggesting it can be used to "remotely care for aging loved ones". It can't tackle steps but does look fairly cute. This feat of technology has an introductory price of $999, rising to $1,499 **–CL**



Intel's new brain

Intel has announced a new version of Loihi, a self-learning neuromorphic chip (Greek: meaning nerve + form) that aspires to mimic the human brain, and is used in neural networks. Loihi 2 will be built using the Intel 4 process node, that's not 4nm, but rather Intel's unique process metric. It was previously called 7nm, although this doesn't match any measurement on the die. This is the first silicon announced for this node, which is due to hit PC processors in 2023. Loihi contains a million artificial neurons and is destined for "neuro-inspired" research projects that aim to build a machine that 'thinks' rather than computes. A Loihi chip may never come to a rig on your desk, but the results of these research projects could be profound **–CL.**

AIRTAG'S HIDDEN DANGER

Lost Mode is open to simple script attack

WE EXPECTED trouble of some sort with Apple's AirTag. The button-sized tracker lends itself to misuse, but we didn't see this one coming. Security researcher Bobby Rauch has uncovered something nasty. If you lose your AirTag, you can activate Lost Mode, which creates a unique address on the Apple servers with a message and contact details. If your lost tag is picked up by a compatible device, you might get a call, and your AirTag back. That's the idea, but the phone number field isn't protected and can be filled with a malicious script instead of plain numbers. This can be used to redirect you anywhere, for example to a spoof iCloud login, where your details can be stolen. A strategically placed AirTag could now become a trap for the unwary.

Apple was told about this vulnerability in June and has been "investigating the matter" since then. Rauch hoped to collect Apple's 'bug bounty', but while Apple promised to fix the bug in a future update, there was no bounty, prompting him to go public. Presumably, Apple will have to fix this sooner rather than later, though the company is notoriously difficult to deal with when reporting security vulnerabilities, being slow to fix them or even unwilling to acknowledge their discovery.

It is unlikely that hackers will launch mass attacks using $29 AirTags, although a targeted attack is more credible. A classic way to infiltrate a network is to leave a USB stick containing malicious code somewhere it can be found, such as in the parking lot of a Department of Defense faculty (that happened). If you do find a lost AirTag, remember that no login is required to get the owner's message, and contact details. **–CL**

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Jarred Walton

TECH TALK

Far Cry 6 Skips Ray Tracing on Consoles

BY THE TIME YOU READ THIS, *Far Cry 6* will be out. It's the first game in the long-running series to support DirectX Raytracing (DXR) and it will be coming out on all the major platforms. Except, the ray-tracing effects will only be available on PCs—the PlayStation 5 and the Xbox Series X and S apparently aren't powerful enough to handle the extra work.

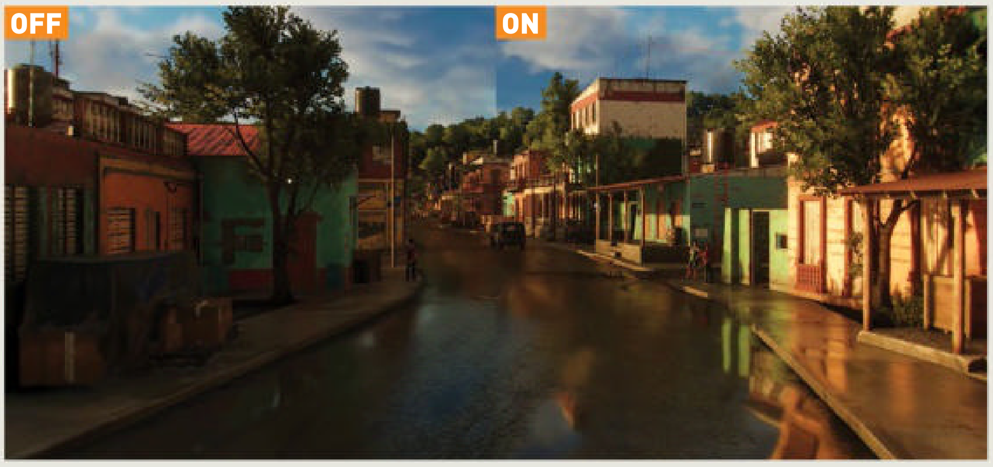
Either that or Ubisoft felt it was more important to hit higher framerates on consoles and that the ray-tracing effects didn't warrant the performance hit. It's another slap in the face for fans of ray tracing, but not without reason. Testing the game with and without ray tracing, the visual gains are more subtle than you'd expect from the drop in performance. However, I'm not convinced that the consoles couldn't have handled the RT workload.

Case in point: the RX 6600 XT only has 32 CUs and ray accelerators, with a 128-bit memory interface. That's slower than any of the latest generation consoles, except for the Xbox Series S with 20 CUs/RAs. The performance at higher resolutions with ray tracing enabled on the RX 6600 XT isn't that bad. At 1080p ultra, it managed 100fps without DXR and 67fps with DXR. That's imminently playable. Even at 1440p ultra with DXR, it averaged 52fps. 4K was a different matter—performance was 38fps without DXR and it tanked to 8fps with DXR. Oops!

The PC version also supports AMD's FidelityFX Super Resolution. The ultra quality mode does 1.3x upscaling in each dimension, so 4K with ultra quality FSR renders at 2954x1662. That's more demanding than 1440p, but performance is 42fps. If you move to higher scaling factors, you can get 50fps by using quality mode, 55fps with balanced mode, and 62fps with performance mode.

The PS5 and Xbox Series X should be a step up in performance from the RX 6600 XT—so imagine our surprise that *Far Cry 6* also omits FSR support on the consoles. There is resolution scaling, though, which might be nearly as good in terms of quality.

It's not just *Far Cry 6* and Ubisoft, though. The first major game with RT support was *Battlefield 5*, launching not too long after Nvidia unveiled the RTX 20-series GPUs. It used RT for reflections and, as an action shooter, maybe it wasn't the best place for improved visuals at the cost of lower framerates. EA has decided to skip RT on the upcoming *Battlefield 2042*, and when you look at the games that use ray tracing, it's not hard to see why.



***Far Cry 6* has ray traced shadows and hybrid reflections, but only on PCs.**

At present, research suggests less than a quarter of all gaming PCs have a ray-tracing capable GPU, and over half of those are the RTX 2060—the slowest of all the ray tracing cards so far. Looking at the image quality improvements from RT in many games only makes the performance hit look less acceptable. We're well into the second generation of RT hardware from Nvidia, and it still feels like it will be a long slog to get more people and developers to embrace the technology. We can at least partly blame the consoles.

The PS5 and Xbox Series X are roughly at the performance level of AMD's RX 6700 XT and RX 6800, respectively. Those GPUs aren't slow, but they're only about as fast as the RTX 2070 and RTX 2080 when it comes to ray tracing. They should be fine for 1080p with RT effects, but with many TVs now running at 4K, we'll need a serious upgrade to the console hardware before RT can begin to go mainstream.

Jarred Walton has been a PC and gaming enthusiast for over 30 years.

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THE LIST

BEST 32-INCH(ISH) MONITORS

8

MSI OPTIX MAG342CQRV

Not a 32-inch screen, but this is the ultimate productivity choice. VA, 100Hz refresh, 3440x1440, for $360.

7

ACER ET322QU

Incredibly well rounded, budget monitor, 1440p, IPS panel, usually available for $245 or so.

LG UltraGear™

6

LG 32GN650-B

This mid-range 1440p monitor comes complete with 165Hz refresh rate and VA panel for punchy colors, $290-400.

5

SAMSUNG ODYSSEY G7

Aimed at gamers, the G7 packs 1440p and 240Hz on a VA panel for punchy pixels, $700-800.

4

LG 32UL500-W

Our first 4K pick is a budget option with a VA panel. And, priced at just $320-350, it's pretty affordable, too.

3

SAMSUNG UR59C

Another 4K VA panel, but this one has better color accuracy for production work, and costs $400-$500.

SAMSUNG
UHD Monitor curved

2

GIGABYTE AORUS FI32U

The ultimate gaming panel, 4K, 144Hz, IPS, 1ms response, all for a decent price of $1000.

ASUS ProArt

1

ASUS PROART PA329C

A color-calibrated king, the awesome ProArt screen has 100% Adobe RGB and sRGB coverage and a 14-bit lookup table. It's also HDR 600 approved and costs $1100.

© ASUS, GIGABYTE, SAMSUNG, LG, ACER, MSI

Ian Evenden

TRADE CHAT

Windows 11 is here, and we'll just have to like it

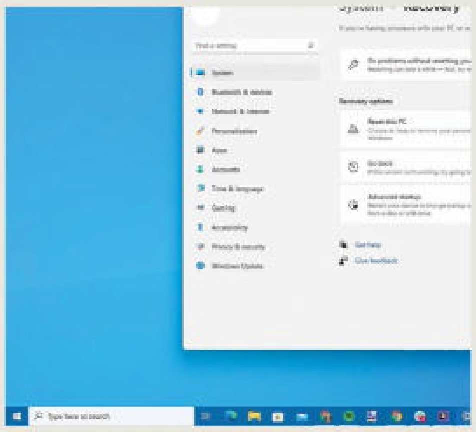
THE GREAT DAY has finally come. As I'm writing, it's early October and Windows 11 is here! Was it worth the wait? It's hard to say on this showing, though our experiences with the preview builds, running in various virtual machines and on spare hardware, has generally been positive. It's worth a wait, though, as already the horror stories have begun to arrive.

Take former *Maximum PC* editor, Alan Dexter. His attempt to upgrade from 10 to 11 ended up with a non-functional chimera, a blend of two operating systems that was far from ideal. It had Windows 10's taskbar, but Windows 11's rounded-cornered windows, and we dread to think what Geiger-esque blasphemy the Start menu would have presented had he been able to pop it up. If ever there was an argument that Windows 11 is just Windows 10 with a facelift, that's it right there. Windows 10.5 is possible, you just wouldn't want to try to use it.

Elsewhere, the wisdom of carrying out a clean installation rather than an in-place upgrade has been borne out. Known issues include compatibility problems with Intel's Killer network drivers; a memory leak in the File Explorer; the Start menu search bar not working; Oracle Virtualbox VMs not starting when Windows 11 is the host; the empty widgets board; and Vietnamese web browser Côc Côc (hello readers in Vietnam!) refusing to play ball. More niggles are bound to be uncovered soon.

Then there's gaming performance. Microsoft's virtualization-based security features host security apps in an area of memory isolated from the rest of the OS so malware can't touch it. This appears to have a deleterious effect on game performance, reducing frame rates by as much as 28 percent, according to tests carried out by our friends at *PC Gamer*. Games such as *Far Cry 6* are less affected, but anyone who is playing *Metro Exodus*, *Horizon Zero Dawn*, or *Shadow of the Tomb Raider* should watch out. VBS is only switched on by default if your PC is from a big OEM, such as HP or Dell. A fresh install on your custom machine's SSD won't apply it unless you want to, and upgrading from Windows 10 won't either.

> Whatever followed Windows 10 was always going to look like a new Vista in comparison



© MICROSOFT

Alan Dexter's Windows 10.5 desktop, with Win 11 Explorer window and Win 10 taskbar.

New OSes always have teething problems, and we're encouraged to upgrade quickly as the new version is always better for gamers. That may be true, and we fell for it with Windows XP and *Thief: Deadly Shadows*' OS exclusivity, but we're still not sure what we got for the price of the upgrade (apart from a decent OS that was superior to Windows Me in every way).

However, Windows 11 must be the first time an OS has launched without many of the features that were used to make the case for having it in the first place. While Auto HDR and DirectStorage appear to be in the release build, Android App support is still absent, even from the Windows Insider dev channel, home of the newest ideas and flakiest builds.

Everything else feels as if it could have been added to Windows 10—we didn't need a new OS just for greater Teams integration and an easier way to toggle between virtual desktops. We didn't need to be put through the gauntlet of TPM and VBS just to get a panel of widgets, something Apple removed from its OS with 10.15 Catalina.

Windows 11 will probably be fine in about a year's time. Coming after Windows 8, version 10 had an easier time of it at launch but has bedded down into such a well-liked and stable OS that whatever followed was always going to look like a new Vista in comparison. Windows 10 was meant to be the last version of Windows, but now we have a new one, and we might as well make the best of it.

Ian Evenden's first PC was a 286 with 640kb of memory. And who could need more than that?

DOCTOR

THIS MONTH THE DOCTOR TACKLES…

> Win11 CPU upgrade
> Crash on wake
> Free up Gmail

Upgrade CPU for Windows 11

I have a self-built desktop based around an MSI X370 Gaming Plus motherboard and AMD Ryzen 7 1700 processor, with 32GB RAM plus a 500GB Samsung EVO M.2 NVMe boot drive and two additional 1TB SATA SSDs as storage. TPM 2.0 and Secure Boot are supported, and I successfully upgraded through the Microsoft Dev Channel to Windows 11 Pro.

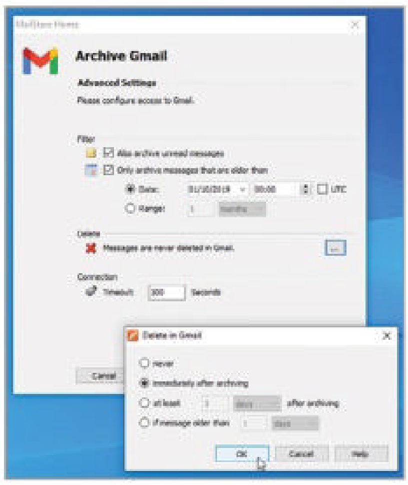
I don't game, the system runs well and I'm happy with its performance. I enjoy using Windows 11 and would love to continue using it once it's released. The problem is that my system doesn't meet the system requirements of Windows 11, due to the first-gen Ryzen processor.

To pre-empt any problems that may crop up with the public release of Windows 11, I've ordered a Ryzen 7 3700x processor. I've already verified that my motherboard supports this processor and that I have the correct BIOS installed to support the processor.

My question is this: if I replace the processor, will that cause problems with my current OS installation? I'm not averse to having to do a clean install but would rather not if I don't have to. My system is completely stable, performs well, and even though I did an in-place upgrade through Windows Update, I see no compelling reason to do a clean install.

So, will a processor upgrade cause any issues that I should be aware of?

—Bobby Sledge


Archive Gmail
Advanced Settings
Please configure access to Gmail.
Filter
Also archive unread messages
Only archive messages that are older than
Date:
Range:
UTC
Delete
Messages are never deleted in Gmail.
Connection
Timeout:
Seconds
Cancel
Delete in Gmail
never
immediately after archiving
at least
after archiving
if message older than
OK
Cancel
Help

Free up online storage by archiving emails to MailStore.

THE DOCTOR RESPONDS: Strictly speaking, swapping out your processor is much less disruptive than replacing your motherboard. In most cases, you should find your system happily accepts the Ryzen 3700x, but there's a small risk it could introduce some stability issues you can't easily resolve.

This is where taking a full drive image of your system using Macrium Reflect Free (www.macrium.com/reflectfree.aspx) takes the stress out of the process. Take your drive image, swap out the processor and see what happens. If you run into problems, swap the processors back, restore the drive image and then prepare to perform a clean install after refitting the new processor again.

Although clean installs are a pain, when you come to perform a major update like that to Windows 11 it's a good idea to consider wiping the slate and starting again, particularly if your current install is two or three years old. Our backup feature from MPC September reveals various tools and strategies that you can employ, such as CloneApp (www.builtbybel.com/ms-apps/cloneapp), for backing up a wide range of program settings.

Malicious browser extension

In the September issue, the first question to the Doctor asks about browser adware that won't go away even after a complete Windows reinstall. I had a similar problem in the past, which turned out to be my router. It was compromised, presumably by someone at my ISP, who had changed my router's primary DNS to a malicious one. A factory reset of the router solved that.

—Micromantic

THE DOCTOR RESPONDS: We've had a few suggestions from readers regarding Gerry Exstein's problem. Long-time subscriber Dennis Rudolph also pointed the finger at the router, suggesting a possible Wi-Fi hack. Again, a factory reset would fix this along with changing the Wi-Fi username and password. It's a good idea to change the router's default username and password too, as a weak password exposes the router to the dangers of remote hacking. Also, check for any router firmware updates or consider replacing the router with a newer, more secure model.

Other readers pointed the finger elsewhere, and we suspect this is the more likely cause of Gerry's problem. Daniel Smith reported suffering a similar problem, which would only manifest after he'd launched Google Chrome for the first time after a reboot. Because

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↘ submit your questions to: doctor@maximumpc.com

Chrome keeps running in the background after being closed, the popups would then continue until Daniel either rebooted his PC or closed all chrome.exe processes via Task Manager. Daniel's workaround was to uninstall Chrome and switch to Firefox, at which point the problem vanished.

Daniel is still keen to troubleshoot the root cause of this problem, and a plausible explanation comes courtesy of a fellow reader, Jif (again via Discord). He points his finger at a malicious browser extension that keeps coming back, even after a full Windows reinstall via Chrome's profile sync feature.

The solution here is to review your Chrome extensions and plugins. Make sure you're signed into your browser profile and visit chrome://extensions/ to see what's currently installed. Make a note of each, then click Details followed by 'View in Chrome Webstore' to review each one in turn, making a note of any reviews that should immediately flag up if the extension is malicious or not.

If in doubt, remove all extensions, allow your profile to sync, and see if that solves the problem; alternatively, switch to another web browser.

Sporadic wake problem

I'm having a sporadic issue: After waking my PC from sleep and completing login, my monitors lose their signals and I hear the fans quit. I can see that there's still power to the LED lights inside the case, but every other device seems to shut down, including the fans and an external drive. When I try to use the power button to restart, nothing happens—whether a simple push or push and hold for 30 seconds. I'm forced to switch off the power to the PSU and back on before the case power switch will start the system back up with the proper startup. This happens only about once every two or three weeks. I built this system about 2.5 years ago and the first time it happened was six months ago, but it is getting more frequent.

My system specs are: Asus Prime X470-Pro, Ryzen 7 2700, ZOTAC RTX 2060 AMP 6GB GDDR6, Trident Z RGB 16 GB (2x8GB) DDR4-3200 RAM, 970 Evo Plus 500 GB M.2-2280 system drive, plus 860 Evo 1 TB SSD for data. Power supply is an EVGA-SuperNOVA G3 750W 80+ Gold, all housed in a Corsair SPEC-02 tower and cooled with a CORSAIR Hydro Series H75 AIO. I'm running Windows 10 Home OES 64-bit. **—Keith Hering**

THE DOCTOR RESPONDS: Our first instincts were that this was a hardware or physical problem. Keith verified that he didn't have fast startup enabled, and checking his event logs revealed no clues, leaving us to suspect the problem may be internal. Before pursuing potential problems with the PSU and motherboard, we asked Keith to power down his PC and investigate inside the case to rule out the possibility of loose metal objects (such as screws) creating a short somewhere. We also asked him to check all cables were securely tied back and connections were secure.

On opening his case, Keith discovered one hold-down screw that wasn't tight, which he rectified. And then he discovered the problem: his vent at the bottom of the case was clogged with dust from the carpet underneath his desk. Keith cleared the dust away and built a 'hardware sled' to sit the PC on. Since putting the PC back together the problem appears to have been resolved. Fingers crossed it stays that way...

AMD Ryzen 7 3700X
AMD
RYZEN
100-000000071
BF 1925SUT
9HP0850R90132
DIFFUSED IN USA
DIFFUSED IN TAIWAN
MADE IN CHINA
© 2019 AMD

Only first-gen Ryzen processors won't support Windows 11.

Gmail storage squeeze

Hi Doc, I've never been the best at organizing my email inbox, but never in my wildest dreams did I think I'd accumulate 15GB of messages. Google is telling me I need to free up space and I'm just too damned lazy to go through my inboxes. I could batch delete entire pages, but that would run the risk of me losing access to important emails from several years ago. How can I bring my Gmail under control with the minimum amount of fuss? **—Kyle Jeffers**

THE DOCTOR RESPONDS: The Doc has traveled down the same road, Kyle, and the days of carefully combing through his inbox to remove or archive messages are long gone. That's partly down to laziness, but primarily due to the sheer volume of messages. Why? Because he has been using MailStore Home (www.mailstore.com/en/products/mailstore-home/) to periodically archive large quantities of email offline.

MailStore can be installed in the usual way, or follow the Doc's example and download the portable version, ensuring MailStore and all your emails are stored in a single folder, which you can then easily back up. Once downloaded and/or installed, launch the app and click 'Archive E-mail'. Type your email into the address field and click Start. MailStore will detect Gmail and whisk you off to your browser to link MailStore to your account.

Once done, a Gmail profile will be created, select this and click Properties... in the right-hand pane to open a wizard. Click Next to access the Advanced Settings, where you should tick 'Only archive messages that are older than' to set a target by date or range (such as six months or two years). Next, you need to click ... under 'Delete' to instruct Gmail to delete the messages once they've been downloaded to your PC—'immediately after archiving' is the Doc's choice. Click OK followed by Finish.

Once set up, click Run. Depending on the size of your mailbox and the amount of mail you're archiving, the process can take several hours or even most of the day, so be prepared to leave it to its own devices. Once complete, go online and empty your Gmail trash to free up the storage space. Once archived, you can access emails directly from MailStore itself—use the left-hand pane to browse by folder or search your mail.

MailStore can also be used to return messages online if you need to—just right-click a message and choose 'Export to → Gmail', then follow the prompts to link up your account and send it back to the cloud.

Windows 11 sleep problem

In the previous issue, Phillip Tursky wrote in with a sleep problem that manifested itself after upgrading to the Windows 11 Insider Update build. We counseled him against pursuing Windows 11 on his 7th-generation system because it's not officially supported and suggested some options to try. Phillip has since been in touch to reveal that the CMOS failed, which he was able to fix by fitting a new CR2032 battery. He also took the opportunity to give his case a good clean and the problem has now been resolved. We're still not recommending running Windows 11 on unsupported systems though. ⏻

PG. 68
STEP-BY-STEP

AMD vs

Sam and **Zak** go head-to-head in an epic integrated graphics PC build-off

PC GAMING, right now, is at a standstill. The computing world has been rocked twice—once by the pandemic, and then again by cryptocurrency. Our humble GPUs have been snapped up and thrown into the deep, dark abyss of crypto mining, toiling away on inane calculations generating value from nothing. Whatever your stance on cryptocurrency, whether you believe it's the future of decentralized finance or a meritless environmental disaster, it's impossible to deny the impact it has had on the industry. As the availability of new GPUs has dwindled, enjoying

AMD INGREDIENTS

PART		STREET PRICE
CPU	AMD Ryzen 7 5700G	$359
Cooler	AMD Wraith Stealth Cooler	$0
Motherboard	Asus TUF Gaming B550M-Plus (WiFi)	$162
Memory	16GB (2x8GB) Crucial Ballistix @ 3600 CL16	$82
Storage	1TB Western Digital Black SN750 PCIe 3.0 M.2 SSD	$126
Power Supply	450W Corsair CV450 80+ Bronze	$45
Case	Phanteks Eclipse P400A	$75
TOTAL		**$849**

PG. 71 STEP-BY-STEP

INTEL

our humble pastime is all but impossible. This generation's mid-range graphics cards are now priced like last year's flagships. Budget options are coming in at $400, and the whole market, although slowly recovering after multiple government crackdowns, is still a place of desolation when it comes to sourcing that most vital of PC components.

So where do you turn, when the GPU's time in the sun is currently stifled? To integrated graphics? Given that processors are currently one of the few areas cryptocurrency can't make a quick buck, it's not a bad shout. For years, we've championed integrated graphics as "just enough" for entry-level 1080p gaming, but as GPUs became more affordable, development in iGPUs stagnated, until now.

With AMD launching its Ryzen G series chips, and Intel declaring its 11th-generation processors packed some of the best graphics performance Team Blue has ever mustered, we decided it was time to put the two to the test by building two similar rigs to truly decide who holds the crown of this generation's iGPU king.

INTEL INGREDIENTS

PART		STREET PRICE
CPU	Intel Core i5-11600K	$270
Cooler	be quiet! Dark Rock TF 2	$94
Motherboard	MSI MAG B560M Mortar WiFi	$160
Memory	16GB (2x8GB) Corsair Vengeance LPX @ 3200 CL16	$74
Storage	1TB Western Digital Black SN850 PCIe 4.0 M.2 SSD	$180
Power Supply	500W be quiet! System Power 9 CM 80+ Bronze	$85
Case	Corsair iCUE 220T RGB Airflow	$115
TOTAL		**$978**

AMD INGREDIENTS

AMD WRAITH STEALTH COOLER $0

There's nothing we love more than a good deal at *Maximum PC*, and a free cooler is right up our street for this build, especially given the price of the Ryzen 7 5700G.

As standard, it comes with the impressively robust Wraith Stealth cooler. This meaty offering packs a serious punch and makes Intel's old and outdated included heatsink look like a paperweight in comparison.

You install this little guy by removing the brackets from the motherboard and using the included mobo backplate to screw it into position. It's not quite as fancy as the be quiet! cooler offered up by the Intel rig below, but it's free! **www.amd.com**

AMD RYZEN 7 5700G $359

The main talking point of this build is the AMD integrated graphics chip, specifically the AMD Ryzen 7 5700G CPU. This chip marks the arrival of the 7nm Cezanne Zen 3 APUs.

This 65W CPU is packed with eight cores and 16 threads, a 3.8GHz base and a 4.6GHz boost clock, 16MB of L3 cache, and eight Radeon RX Vega CUs that operate at 2.0GHz. It looks pretty tasty on paper, it's a Zen3 chip too so it steps up to a DDR4-3200 interface from DDR4-2933. This will certainly aid gaming performance with the integrated 7nm Radeon RX Vega graphics engine. It should produce solid 1080p gaming and for our battle, that's exactly what we are aiming for. **www.amd.com**

450W CORSAIR CV450 80+ BRONZE $45

We have gone for a budget-priced PSU in this build, which is more than capable of powering our machine. With no traditional radiator AIO and no GPUs, we don't necessarily need a huge powerhouse PSU. It's a non modular power supply, which does hinder cable management a bit. Ideally you want to remove cables you're not using (such as any PCIe power and of course those excess SATA cables that are going to take up space in the bottom half of the case).

Another downside is if a cable gets damaged, replacing it may be a pain in the backside. Sure, the 80+ bronze efficiency rating isn't what we would have in a more premium build, but at such a budget price tag, we can't complain. **www.corsair.com**

ASUS TUF GAMING B550M-PLUS (WI-FI) $162

There are plenty of motherboards to choose from, but ASUS boards have worked well for us before and this TUF GAMING B550M-PLUS Micro-ATX is a solid pick. It has upgraded power delivery and comprehensive cooling options to fuel the latest AMD Ryzen CPUs. With BIOS FLBK support, it is easy to set up and install too.

The socket for this board is the AMD AM4 socket, making it ready for 3rd Gen AMD Ryzen processors and 3rd Gen AMD Ryzen with Radeon graphics processors. It also has next-gen connectivity with PCIe 4.0 M.2, USB 3.2 Gen 2 Type-A, Type-C, and WiFi 6 support. This should go well with our AMD Ryzen 7 5700G. **www.asus.com**

WD_BLACK
SN750

1TB WESTERN DIGITAL BLACK SN750 PCIE 3.0 M.2 SSD $126

This Western Digital SN750 is a sleek SSD with a design that accommodates most PC builds and the heatsink fits in nicely with our mobo. It should cut game load times, improve overall performance and allow for a solid 1080p experience. It doubles storage density from the last generation with NAND technology.

The SSD also is great when using the WD_BLACK SSD Dashboard, as it allows you to optimize performance with the gaming mode. It disables low power mode on the SSD and makes sure it is running at full power. With sequential read speeds of 3470MB/s and sequential write speeds of 3000MB/s, it's no slouch. **www.westerndigital.com**

BALLISTIX
ELITE
BALLISTIX

16GB (2X8GB) CRUCIAL BALLISTIX @ 3600 CL16 $82

There is always an abundance of RAM sticks to choose from when building a PC. RAM speed was our main priority, as this matters more for AMD CPUs than Intel chips. AMD CPUs have a cut-off speed of 3733MHz, so ideally we would have had some of those in this build. However, these Crucial Ballistix DDR4 sticks run @3600MHz. 16GB is a good amount, but this can always be increased, the price swayed us—under $100 is good for sticks of this speed. It isn't the most interesting choice, but we weren't going for a specific aesthetic. RGB is always an option, but if you want to tone things down a little, this all-black Crucial Ballistix memory kit is a good choice. **www.crucial.com**

! PG. 68
STEP-BY-STEP

PHANTEKS ECLIPSE P400A $75

This all-black ATX mid-tower case from Phanteks is a great choice for this build and a majority of other builds too. With an angular mesh front panel, the case looks sharp and strong with plenty of intake airflow. The front I/O contains two USB 3.0 ports, a mic and headphone jack, a reset button, and a three-speed fan controller. With the great airflow and fan controller built-in, you can tell this case has been made with airflow in mind.

It comes with two 120mm fans with enough room for six 120mm fans if you need them or you want your PC to take off. It supports ATX, Micro-ATX, Mini-ITX, and E-ATX so it's pretty darn compatible. Paired with some great cable management, there's not much we can say that is wrong with this case. **www.phanteks.com**

18+

WHAT IS
AVAXHOME?

AVAXHOME -

the biggest Internet portal, providing you various content: brand new books, trending movies, fresh magazines, hot games, recent software, latest music releases.

Unlimited satisfaction one low price
Cheap constant access to piping hot media
Protect your downloadings from Big brother
Safer, than torrent-trackers

18 years of seamless operation and our users' satisfaction

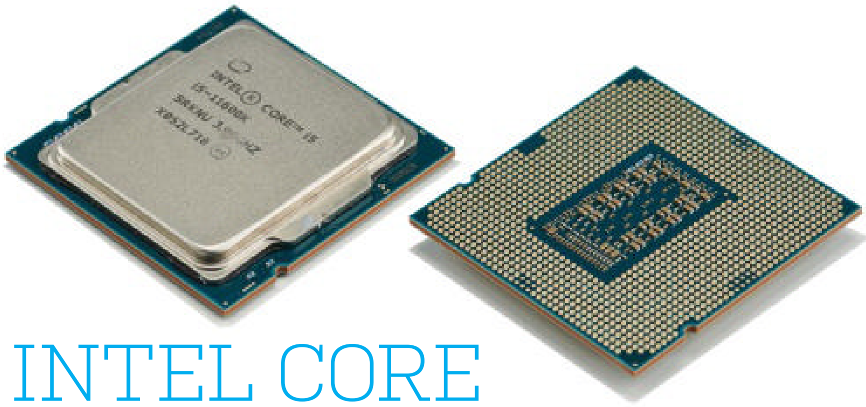
All languages
Brand new content
One site

AVXLIVE.ICU

AvaxHome - Your End Place

We have everything for all of your needs. Just open https://avxlive.icu

INTEL INGREDIENTS



INTEL CORE I5-11600K $270

A Maximum PC regular, the Core i5-11600K is perhaps the best of Intel's latest generation of processors. Featuring six cores, 12 threads, 12MB of cache, and a turbo clock speed of up to 4.9GHz, it's a 95W 14nm monster based on the Rocket Lake architecture.

Other headline features include PCIe 4.0, but we're most interested in the integrated graphics. The 11600K delivers Intel's latest UHD Graphics 750 config, with a max dynamic frequency of 1.3GHz, 32 Execution units, and the ability to drive displays up to 5120x3200 @ 60 Hz. It also has support for DirectX 12, OpenGL 4.5, and a number of interwoven Intel GPU features too. But is it enough to beat the competition? **www.intel.com**

BE QUIET! DARK ROCK TF 2 $94

Unlike our competition over on Team AMD, the Core i5-11600K doesn't come with its own cooler. So, we've teamed up with be quiet! to bring its latest Dark Rock TF 2 to bear on the plucky hex-core chip. With a super sleek design, twin fan construction, and epic six heat-pipe design, this twin pseudo-low-profile CPU cooler can chill any chip capable of running at near 230W of TDP, and at an impressively quiet 27.1dB(A).

Each manufacturer measures TDP differently, but this thing is more than capable of cooling even the Core i9-11900K. It also packs in a three-year warranty, and the fans even have a rated lifespan of 300,000 hours at 25C. **www.bequiet.com**

MSI MAG B560M MORTAR WIFI $160

Magnificent? Magnum? Magnetic? MSI hasn't told us what "MAG" stands for in its latest line of motherboards, but this is the board that we picked to house our plucky little chip.

Complete with a sleek aesthetic and plenty of connectivity, the B560M Mortar comes highly recommended, and packs in exactly what we need, including a PCIe 4.0 slot for our M.2 of choice, a ton of onboard connectivity, including WiFi 6E and a 2.5G LAN port, and lastly both an HDMI and DisplayPort to go with that integrated GPU. On top of that, we can pop a GPU (when they're available) in the topmost PCIe slot and take advantage of that PCIe 4.0 x16 connectivity as well.

For a B series board at $160, this thing is rammed with future-proofed goodness. **www.msi.com**

500W BE QUIET! SYSTEM POWER 9 CM 80+ $85

We'll say this until we're blue in the face but get a decent power supply. You don't have to spend a lot, just buy from a brand you trust, even if it has an 80+ rating, and is non-modular. There are so many dodgy PSUs with subpar components out there that could take your system out, it's not worth the risk.

Take our faulty RGB controller tripping the entire build. It shot the power supply instantly, but the rest of the rig, the motherboard, the CPU, were all fine—protected by some ingenious engineering from this German manufacturer.

The System Power 9 CM is a fine little unit, with plenty of cables, and modular too. At 500W, it's got plenty of headroom for our system, and will even support an RTX 3080 (if they're ever in stock again). Oh, and it's… quiet. **www.bequiet.com**

PG. 71
STEP-BY-STEP

1TB WESTERN DIGITAL BLACK SN850 PCIE 4.0 M.2 SSD $180

So as we said earlier, our plucky little Core i5, supports PCIe 4.0 where the Ryzen 7 5700G does not. Advantage Intel. And we're going to take advantage of that advantage with this speedy little number from Western Digital. A counterpart to the SN750 featured in the AMD build above, the SN850 packs in 1TB of high-speed PCIe 4.0 NAND Flash goodness for just under $180.

Performance is better than you'll see in its predecessor PCIe 3.0 part. We're talking sequential read speeds of 7,000 MB/s and writes at 5,300 MB/s. For IOPS? 1 million 4KB Random Read and 720K Random Write—even the failure rate is impressive at 1.75M hours of use. What's not to love? **www.westerndigital.com**

16GB (2X8GB) CORSAIR VENGEANCE LPX @ 3200 CL16 $74

So, the motherboard supports up to 5,066 MT/s memory, but let's be real, that stuff is still crazy expensive, and unless you're editing 8K video with a Core i9 (which, let's face it, you wouldn't be doing on a B550 board anyway), you won't need it.

In fact, even looking at a 5000 MHz kit of Corsair Vengeance LPX makes us cry, seriously. $1,075 from Corsair, for 16GB of 5,000 memory with a CAS latency of 18. So, the speed is impressive, and the latency epic, but not at that price. 16GB at 3200 will be more than enough for everything we need here, and better yet, the low-profile element of these bad boys gives us plenty of clearance for the cooler too **www.corsair.com**

CORSAIR ICUE 220T RGB AIRFLOW $115

Last but by no means least, we have our case for this build, and that's the trusty Corsair iCUE 220T RGB Airflow. Now, it's getting a little long in the tooth at this stage, but as Corsair doesn't have a budget successor for it just yet, it's still perhaps one of the best (sort of) budget cases you can buy.

Perhaps unsurprisingly, the airflow with this chassis is impeccable. Even better than the Phanteks Eclipse P400A above. The reason behind it (aside from the triple fans), is that Corsair has expertly designed the front of the case with these triangular boomerang cutouts, instead of applying a mesh filter over the top. Contrary to popular belief, mesh filters actually impede airflow compared with a proper cutout. They create turbulence, and make it difficult for a fan to draw air through. Cutout panels like this one provide far larger gaps for that air to be drawn through, meaning lower temperatures inside your rig.

Aside from that, it comes with a set of three RGB 120mm fans as standard, and plenty of mod cons to make your building experience pretty seamless. And it's available in black or white finishes. The only downside? We wish it had a fan controller as well as an RGB controller. **www.corsair.com**

CHOOSING BENCHMARKS

The world of integrated GPUs isn't cut out for our usual suite of tests

FOR MOST OF OUR TESTING, we typically have a set list of benchmarks designed around being run on systems with dedicated GPUs. Most of the time, that involves running X game at Y resolution—usually on the highest graphical settings profile the game comes with as default. That way, it makes it easy for you at home to replicate those same tests with your own machine. It also gives you a better idea of how your rig scores in comparison and, of course, gives us a level playing field to work with when it comes to carrying out any similar testing in the future.

The problem with that is, in the world of integrated graphics, those kinds of benchmarks are grossly unfair to small integrated GPUs, such as the ones featured in these two builds. Yes, integrated graphics have come a long way over the years, and they are far from being stuck operating as media PCs and home office machines today, but throwing *Total War: Warhammer II* at an iGPU at 1080p Ultra is just cruel. Nor will it give us an accurate representation of how this chip would perform under more reasonable and realistic circumstances.

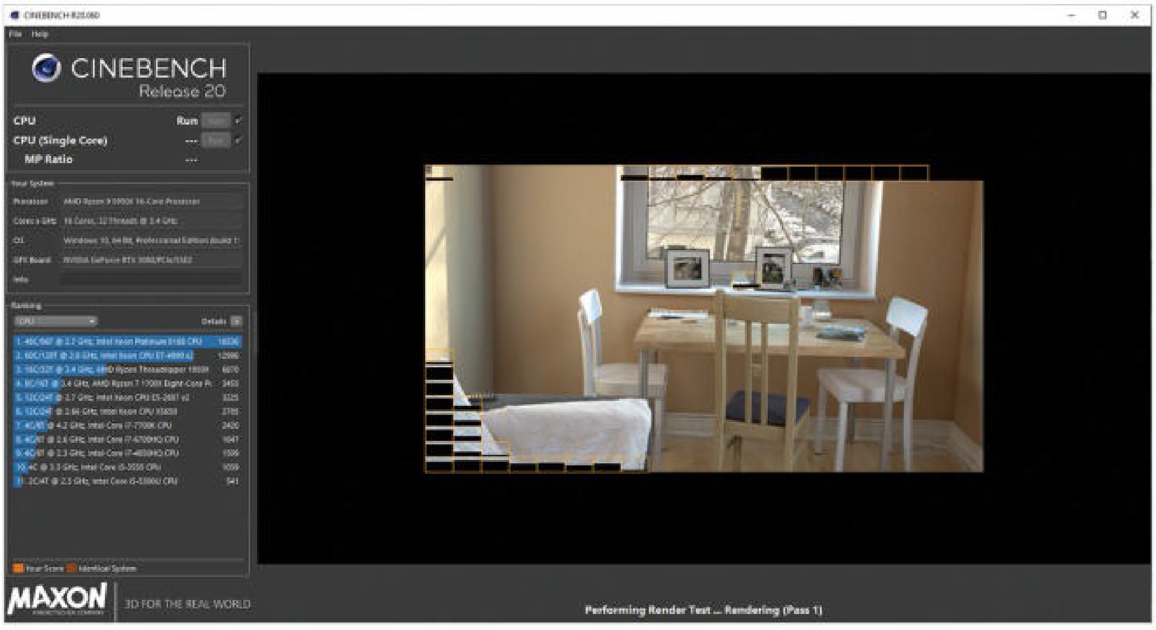
Total War is perhaps the best example of a CPU-intensive title from our testing suite. It's a game we choose specifically because it stresses the processor during regular benchmarking. In fact, most games (particularly single-player titles) generally leverage most, if not all, of the stress onto the GPU, rather than the CPU, or both. Strategy games, however, with their many thousands of individual units, and some online games too, really do push processors hard.

Ultimately, you can have all the high-speed memory in the world, but it's just not going to be enough to manage *Total War* at 1080p Ultra on an iGPU, no matter what. And that's often reciprocated in our benchmark figures for builds like this. It's not unusual to see scores of 5 or 6fps in these tests on our usual platform and, obviously, that won't do.

So, for this feature, we have decided to shake things up and do something a little different with the benchmarks. This time, we're going to be testing a selection of games at 1080p specifically, but across three separate presets instead, Low, Medium, and High, no Ultra in sight. The games are still challenging, and still comparable to the ones we regularly use in our usual suite, but it should give us a better indication of what you can expect from your iGPU PC. But we're not stopping there either! Oh no.

GAMING PERFORMANCE

First up on the chopping block are the game benchies. In this case, we're going to be testing *Total War: Warhammer II*, *Middle Earth: Shadow of War*, and *Assassins Creed: Valhalla* (all the colons) at 1080p low, medium, and high presets.



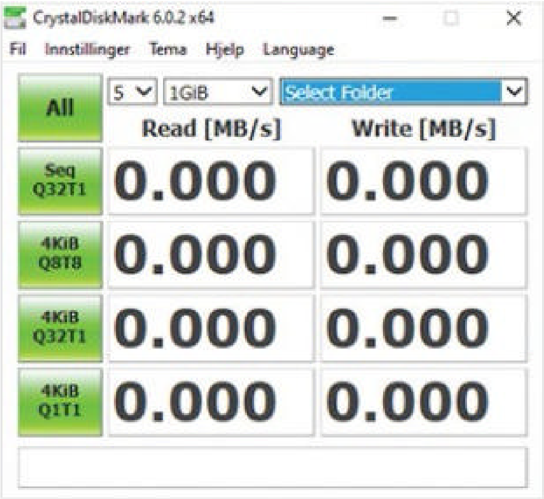
CineBench is a staple rendering test that pushes your processor to the limit.

This gives us a nice mix of titles to draw upon, including an older, neutral AAA game from 2017, in the form of *Shadow of War*, a brand new AMD-optimized AAA title in *Valhalla*, and an Intel optimized strategy game in the shape of *Total War*. All with included easy-to-run benchmarks.

On top of that, we're also going to be performing some more "old-school" synthetic tests, namely 3DMark's Fire Strike and Time Spy tests at 1080p. These will provide us with an index we can refer to, to see how far we've come from generation to generation, and also let us test performance both with DX11 (Fire Strike) and DX12 (Time Spy).

COMPUTATIONAL PERFORMANCE

With gaming out of the way, it's also important we take a quick look at the synthetic computational element of these two builds too. Both offer vastly different architectures and performance figures because of it. To do this, we've grabbed



CrystalDisk shows how our SSDs perform

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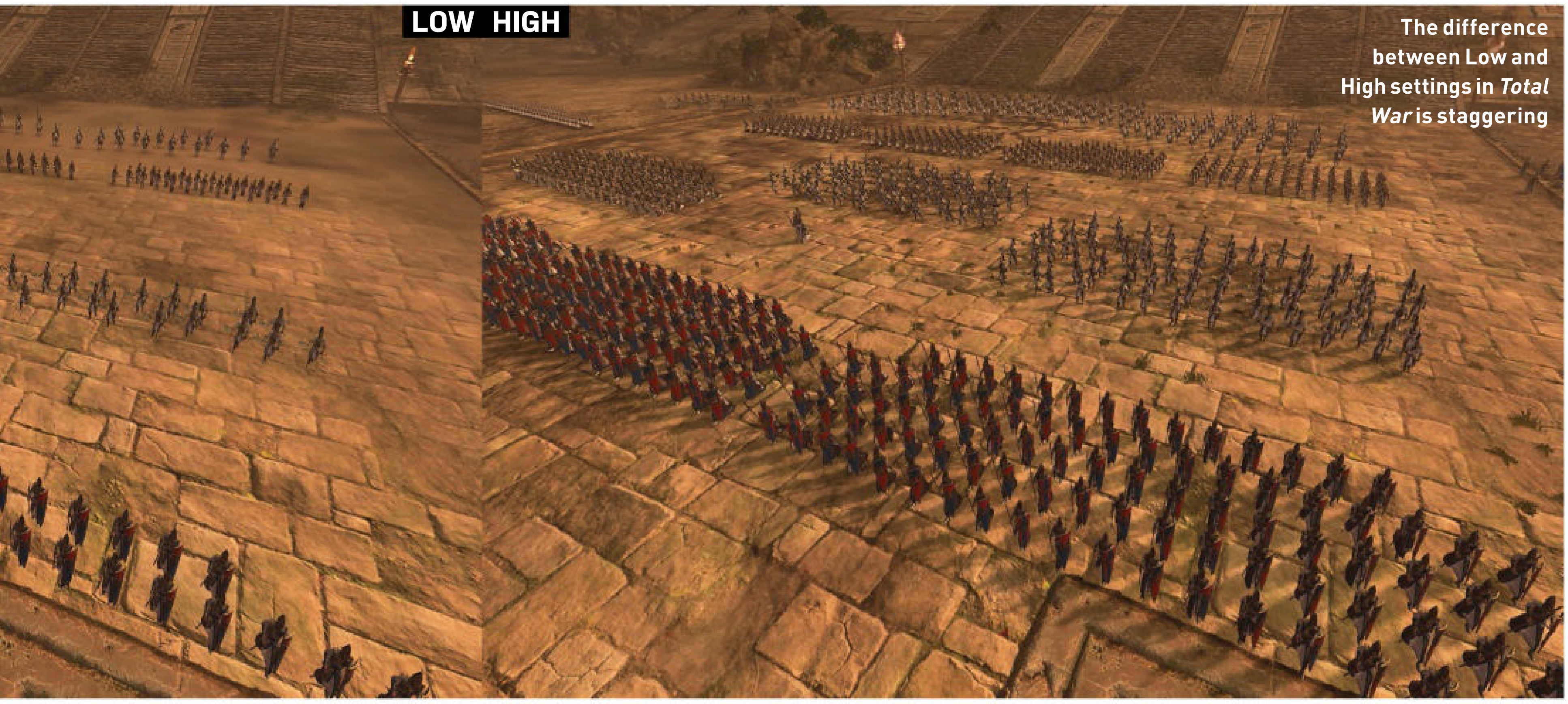


The difference between Low and High settings in *Total War* is staggering

some basic, easy-to-run, synthetic tests that you can use yourself at home.

For processing performance, we'll be using CineBench R20 (you can download it yourself for free from here: bit.ly/Cine20MPC) to test out our processor performance, taking advantage of both its single-core and multi-core metrics.

And finally, to test out our SSD performance, we'll also be taking a quick look at CrystalDiskMark 6 (bit.ly/CD6MPC). This should give us an accurate representation of how our two SSDs perform under pressure, namely looking at Sequential read/write speeds at a queue depth of 32, 1 thread, and also Random 4K read/write speeds at a queue depth of 1, 1 thread.

Sequential performance is indicative of reading or writing files that are stored close to one another on the drive itself (for instance, your photographs, videos, and media files, things like that), whereas Random 4K testing is more indicative of something like a game reading and writing to a variety of different locations on the drive at any one time. This is almost always more difficult to do than with sequential data, thus the far lower numbers in the tests.

As neither of these systems was really cut out to be video-rendering machines, workstations, or anything of the like, due to a lack of dedicated GPU, which massively accelerates these workloads, we're going to skip out on any memory testing or power-draw this time around.

So, ultimately, what we're left with is purely an exercise to see which integrated graphics solution is superior to the other.

FUTURE PROOFING PICKS

So, you've seen our two builds, looked at the parts, and wondered about the future. After all, investing in a rig like this is usually going to future-proof you for the next five years, and with both AMD and Nvidia expecting silicon shortages to end from mid-2022, the chance of getting a graphics card at a reasonable price doesn't seem far away.

So, what happens if you add a GPU to either of these two systems? Traditionally, AMD's Ryzen G processors used to feature a reduced number of PCIe lanes for graphics. In fact, with the 3000 G series, it was half that of what you'd find on the non-APU equivalent or Intel's chips (x8 not x16 lanes). That meant most GPUs would be bottlenecked by a lack of bandwidth as the lanes just weren't there. x8 PCIe 3.0 lanes equates to around 8GB/s (or 64Gb/s or 4GT/s whatever takes your fancy) of maximum bandwidth, whereas x16 doubles that figure leading to a max of 16GB/s. The latest generation, PCIe 4.0, doubles those figures again, so you end up with a max bandwidth of 32GB/s across a x16 slot port, and so forth.

Now, we have yet to saturate the PCIe 3.0 x16 slot, 16GB/s is more than enough bandwidth to facilitate even the most high-end graphics card. That said, x8 lanes isn't, and you typically end up with a reduction in frame rate of between 5-20%. Fortunately, AMD has redesigned its latest APUs to include x16 graphics PCIe lane support. It's still PCIe 3.0, but if you add a full-sized GPU, you shouldn't see any performance degradation, unlike what we saw back with the 3000 series. Good stuff.

The only concern is what AMD and Nvidia produce in terms of their next-gen GPUs, and how large the performance delta will be compared with the previous generation. We expect to see both the RTX 4000 series and RX 7000 series cards launch next year. AMD will likely have packed some dedicated hardware in for ray-tracing and Nvidia will be going harder than ever, due to the increased competition from the RX 6000 series.

It could be the year that we finally eke over that 16GB/s PCIe 3.0 x16 lane bandwidth limit, at which performance may begin to drop with our AMD Ryzen 7 5700G series processors (along with every other PCIe 3.0 chip, including Intel's 10 series parts too).

These things are hard to predict, and the performance difference may be less than 10% so it's a fairly negligible worry, but it's worth considering if you plan to invest in a GPU later on.

! PG. 68 STEP-BY-STEP

AMD CONCLUSION

OH BOY, did we get some results in this test. It wasn't necessarily what we had hoped for, but this is a test of the integrated graphics on each side of the battle, AMD and Intel. In an ideal world, we would accompany these CPUs with some hefty GPUs that would improve performance, but it's a test of iGPUs, not discrete GPUs.

On the AMD side of the head-to-head, the build itself was plain sailing to piece it all together, and yet the opposite once we tried to boot things up for the first time. With nothing but a blank display, we updated the BIOS (which was fairly easy as our ASUS mobo has a BIOS FLBK port on its I/O) and then used a USB Windows 10 installer to get it ready for testing.

Once the machine powered on, we then installed the relevant drivers for the motherboard and the chipset to get the AMD APU up and running properly, or so we thought. After some initial testing, our results weren't what we expected. Taking a peek at the memory using CPU-Z, it was clear the DDR4 was running at 2,666MT/s, not the 3,600 it's specced at. Jumping into the BIOS, we realized we'd forgotten to enable the XMP profile, so the speed and timings were out (rookie error!). To do that, we set the Ai Overclock Tuner profile to the DOCP option. This is AMD's alternative to XMP (eXtreme Memory Profile) usually found on Intel motherboards.

For AMD, with Asus motherboards, it's located inside of the Ai Tweaker menu. This should enable the XMP settings found on the RAM (increasing timings, frequency, and voltage in the process) and tell the motherboard to use the full speed the kit is capable of running at. RAM frequency matters to AMD chips, and for our PC to work at its best, it needs the full 3,600 MT/s that our Crucial Ballistix RAM should be providing.

Unfortunately, after applying the DOCP profile, the machine kept rebooting and failing to post. So, we headed back to the BIOS and declocked the frequency down to 2,800 MT/s, to see if it would boot at a higher speed than the original stock settings outlined by JEDEC. Thankfully it did, but this was still an issue as we needed the memory speed to be working at its fastest. We kept restarting the PC and booting it up with a higher memory frequency each time to see what would stick but, unfortunately, the best we could get out of these sticks was 3,133 MT/s. It's not awful, but we didn't choose 3,600 MT/s sticks to underachieve like that, and these APUs love faster memory.

SYNTHETIC TESTS

	ZERO-POINT	
CineBench R20 Single (Index)	572	576 (1%)
CineBench R20 Multi (Index)	4,157	5,367 (29%)
CrystalDisk QD32 Sequential Read (MB/s)	6,983	3,265 (-53%)
CrystalDisk QD32 Sequential Write (MB/s)	5,175	2,952 (-43%)
CrystalDisk QD1 Random 4K Read (MB/s)	81	46 (-43%)
CrystalDisk QD1 Random 4K Write (MB/s)	247	150 (-39%)
3DMark: Fire Strike DX11 (Index)	2,098	3,835 (83%)
3DMark: Time Spy DX12 (Index)	792	1,547 (95%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

GAMING TESTS

	ZERO-POINT	
Total War Warhammer II @ Low	20	34 (70%)
Total War Warhammer II @ Medium	17	28 (65%)
Total War Warhammer II @ High	14	25 (79%)
Middle Earth: Shadow of War @ Low	15	28 (87%)
Middle Earth: Shadow of War @ Medium	13	24 (85%)
Middle Earth: Shadow of War @ High	9	17 (89%)
Assassins Creed: Valhalla @ Low	12	28 (133%)
Assassins Creed: Valhalla @ Medium	7	22 (214%)
Assassins Creed: Valhalla @ High	5	17 (240%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Average frame rates reported for games. All tests were performed at 1080p on the indicated graphics preset. Zero point consists of an Intel Core i5-11600K, 16GB of DDR4 @ 3200, and a 1TB WD SN850 M.2 PCIe 4.0 SSD.

The only other memory we had spare were some 3,200MT/s G.Skill Trident Zs. Out of curiosity, we looked at whether we could get more performance out of these. Again we could only get a stable boot when configured to 3,000MT/s, so Crucial's offering still works better here.

Results were lackluster compared with what we're used to seeing from a discrete GPU, of course, but that's to be expected. After getting around 30fps on low presets on some games, our hopes for smooth 60fps, 1080p gameplay were dashed. The benchmark results speak for themselves. Ideally, you don't want to settle for a low preset, but anything less than 30fps isn't acceptable by today's PC gaming standards. SSD read and write speeds, however, were a high point of this build and for normal day-to-day usage, so while it works pretty well as a daily driver, it's not so good if you intend to do any high-end gaming.

Lacking a GPU and RAM sticks that run at their full potential hold this machine back from achieving a smooth Full HD gaming experience. If we had sticks that were fully compatible with our motherboard, we may be looking at a different outcome (reports even suggest up to 10-15% additional performance).

Still, the results were much higher than our Intel competition, and in older games or less graphically intense titles, such as *Minecraft*, *Hades*, or *Roguelikes*, it's an ideal PC to get your foot in the door. It just depends on what you play. Mainstream games, yes. AAA titles, no. **–SL**

! PG. 71 STEP-BY-STEP

SYNTHETIC TESTS

	ZERO-POINT	
CineBench R20 Single (Index)	576	572 (-1%)
CineBench R20 Multi (Index)	5,367	4,157 (-23%)
CrystalDisk QD32 Sequential Read (MB/s)	3,265	6,983 (114%)
CrystalDisk QD32 Sequential Write (MB/s)	2,952	5,175 (75%)
CrystalDisk QD1 Random 4K Read (MB/s)	46	81 (76%)
CrystalDisk QD1 Random 4K Write (MB/s)	150	247 (65%)
3DMark: Fire Strike DX11 (Index)	3,835	2,098 (-45%)
3DMark: Time Spy DX12 (Index)	1,547	792 (-49%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

GAMING TESTS

	ZERO-POINT	
Total War Warhammer II @ Low	34	20 (-41%)
Total War Warhammer II @ Medium	28	17 (-39%)
Total War Warhammer II @ High	25	14 (-44%)
Middle Earth: Shadow of War @ Low	28	15 (-46%)
Middle Earth: Shadow of War @ Medium	24	13 (-46%)
Middle Earth: Shadow of War @ High	17	9 (-47%)
Assassins Creed: Valhalla @ Low	28	12 (-57%)
Assassins Creed: Valhalla @ Medium	22	7 (-68%)
Assassins Creed: Valhalla @ High	17	5 (-71%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Average frame rates reported for games. All tests were performed at 1080p on the indicated graphics preset. Zero point consists of an AMD Ryzen 7 5700G, 16GB of DDR4 @ 3133, and a 1TB WD SN750 M.2 PCIe 3.0 SSD.

INTEL CONCLUSION

☆☆☆☆☆☆☆☆☆☆☆☆

WHAT A RIDE this whole build process has been! If you skip to page 68, you can read about how our Intel build went "pop" during the photo shoot, taking out a power supply. We don't know why, a fault somewhere along the line, maybe? But one fresh PSU later and we're good to go.

Fortunately, unlike our Team Red competition, the Intel build's install process went a lot smoother. As we don't technically rely on high-speed memory in anywhere near the same capacity, what you get with this build is exactly what you get. Theoretically, we could add higher-speed memory, maybe go for a 3600 or 3733MT/s kit, but the only area we'd see performance increases would be in video-editing applications and maybe in Adobe Photoshop or similar programs. It's not worth the extra investment unless you can find them cheaper due to greater availability (or a kit that doesn't come with some flashy RGB).

You'll notice I'm delaying talking about how the Intel rig did in terms of in-game performance. That's because, if we were to sum it up in two words, it'd be "not good". Not "not good" as in an "oh man, this system doesn't have a discrete GPU, how terrible is the performance at 1080p" sort of way, but in an "oh man, this system can't compete with AMD, despite costing more, and the performance is worse at 1080p" sort of way. Yeah, that kind of "not good".

Our highest recorded average frame rate was 20fps in *Total War*, on Low at 1080p. The lowest figure was in an admittedly AMD-optimized title, *Assassins Creed: Valhalla* with a whopping 5fps on High. That's not good. This is Intel's latest UHD 750 graphics and it doesn't hold a candle to that inside the Ryzen 7 5700G or even its cheaper sibling. This is a shame, because Intel's Iris stuff is genuinely impressive, certainly on laptops. Perhaps it's a limitation due to the size of the processor, or complexity due to architecture design (Intel still uses a monolithic chip design that's costly and difficult to develop), but the lack of Iris graphics makes AMD the go-to choice for those looking to build a budget gaming PC.

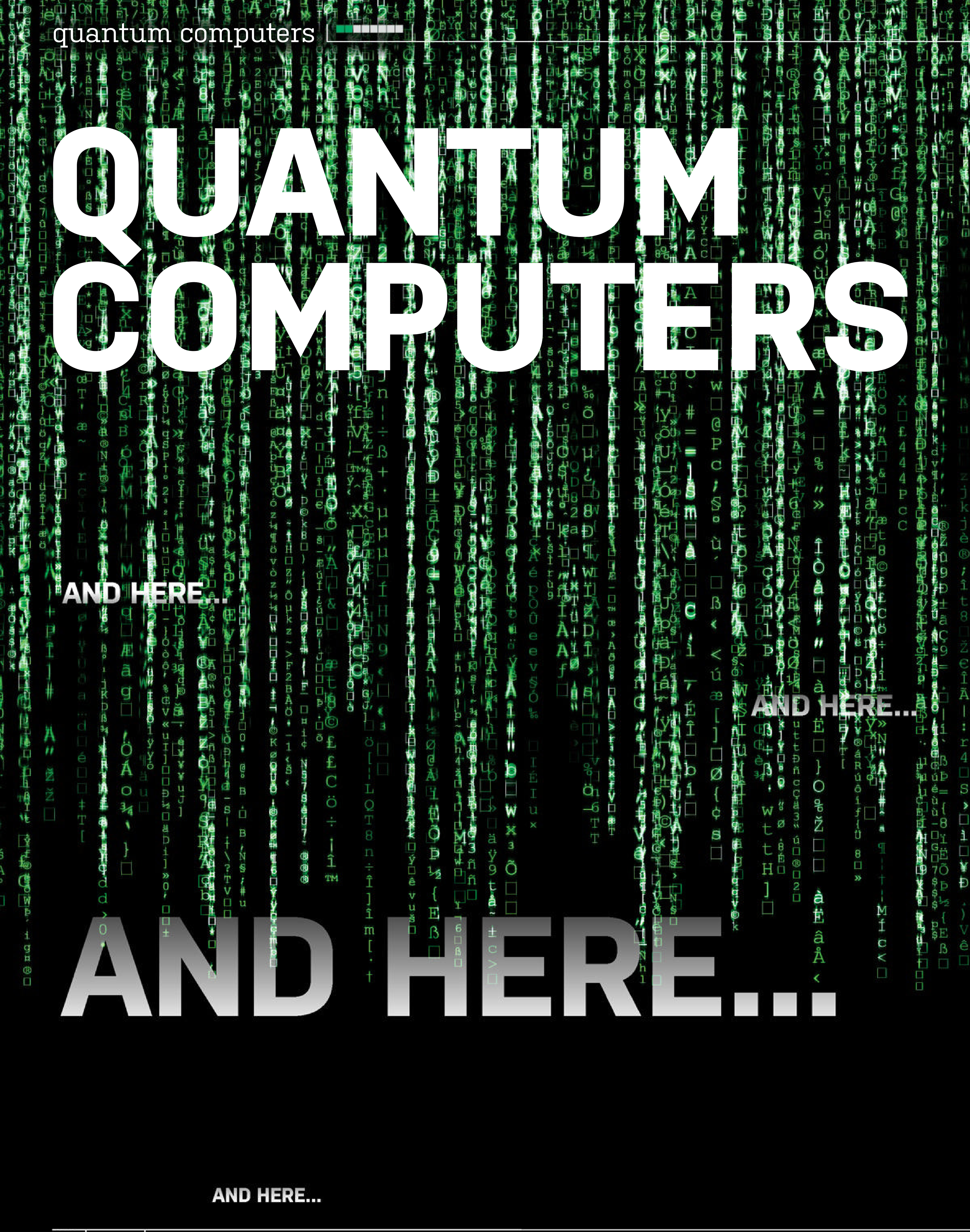
The story gets better when you play some less intensive titles, such as *Hades*, *Minecraft*, and *Crusader Kings III*. All of them performed well, averaging 30-40fps, making them more than playable, even *Divinity: Original Sin 2*, and *Prison Architect* were enjoyable experiences. So maybe it's not hitting that 60fps sweet spot, but you don't need to play AAA titles to have fun, and both of these machines represent a significant leap over past generations in terms of that capacity. That said, with either build, you'd almost always be better off getting a dedicated GPU if you could right now.

Apart from that, the big winner for Intel was in the PCIe 4.0 performance. WD's SN850 PCIe drive ran rings around its PCIe 3.0 predecessor, clocking in substantially higher scores, sequential reads were twice that of the SN750, and writes almost double, with a similar story on the Random 4K situation too.

So, then, AMD wins. For the time being, Intel can't quite keep up, even with an unlocked Core i5 and an advanced cooler on top of it. Admittedly, the 5700G is considerably more expensive than the i5, but even the 5600G clocks in similar performance (although with two fewer cores), and that's a processor that comes in at around $260, $10 cheaper than the Intel chip, and includes a cooler too.

If you want to run an iGPU system, don't care about AAA titles, and are happy with that PCIe 3.0 limitation, Team Red is rightly king of the hill. However, if you're looking for something to tide you over until you invest in a next-gen GPU, Intel still holds the iGPU candle there, at least for now. With both AMD and Intel ramping up to launch new processors, it may not be long until the battlefield shifts once more.

It's a tale as old as time, Blue vs Red, Intel vs AMD—no doubt this battlefield will be revisited again soon, and that's no bad thing, at least not for us. **–ZS**



QUANTUM COMPUTERS

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The first quantum computers are being delivered to researchers and supercomputing centers. What will we do with them? *Ian Evenden* finds out.

QUANTUM COMPUTING is one of those technologies that seems forever just over the horizon, much like the flying car or an iPhone that lasts all day on a single charge. Developments come and go, announcements are made, each sounding crazier than the last, but tangible benefits never seem to appear.

Physicist Richard Feynman, one of the first to conceive of a quantum computer, due to his interest in the relationship between physics and computation, often has a quote attributed to him—it's possibly apocryphal, but most certainly apt: "If you think you understand quantum mechanics, then you don't." The same is almost certainly true of quantum computing, where there are so many new terms and variables to consider, it seems impossible for a single human brain to hold them all. The fact that so many of them sound like science fiction is perhaps part of the discipline's appeal.

Having multiple approaches to solving the same problem certainly keeps the scene lively, and we envisage endless debates between scientists along the lines of whether Intel or AMD is best, and whether the cryogenic cooling plant really needs all that RGB. It also means that we've had a solid run of news announcements and tech demonstrations recently, as work held up by the pandemic begins to bear fruit.

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BENDING THERMODYNAMICS PROBABLY...

Take time crystals. Yes, really. Despite sounding like something the Emperor Zog is searching for, protected by a plucky band of heroes including at least four kids and a puppet, a time crystal is a real thing: Google has made them using a quantum computer.

Emperor Zog can relax, however. A time crystal has possible practical uses as quantum memory or as a sensitive detector of quantum fields but isn't going to destroy the universe. Imagine a system of particles in its lowest energy state, meaning it cannot lose any more energy to its environment, yet remaining in motion. The particles cannot come to rest because they are already in their quantum ground state, and usually would be still, but remain moving. It sounds like perpetual motion does an end-run around the second law of thermodynamics, but it has been demonstrated by a team from Stanford, MIT, and Google using Google's Sycamore quantum processor.

Being in motion means it can flip between two states without losing energy, in theory doing this forever like a pendulum that will never stop swinging. MIT physicist Frank Wilczek wasn't involved in the work, but he hypothesized the existence of time crystals back in 2012. "They can be sensitive probes of certain kinds of external fields, so they will give us, in principle, new kinds of exquisitely sensitive devices," he told *New Scientist*.

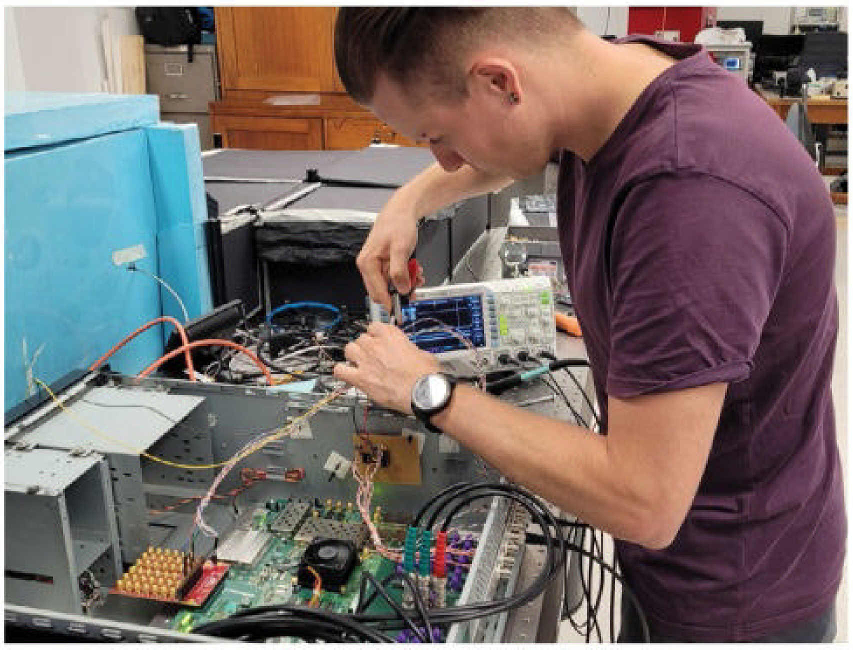
The other thing about quantum computing is that there are so many approaches. It's as if the early pioneers of our CPUs couldn't agree on a material to make transistors out of, and instead split into factions, one using silicon, another using luminiferous ether, and another using cheese. They all work, and arguments persist about which is the best way of creating one.

Google's Sycamore computer is an example of one kind of processor, the superconducting quantum processor. This is the sort of technology most commonly associated with quantum computers and requires cooling systems that chill them to within a fraction of absolute zero. Under these conditions, the qubits—the quantum equivalent of bits in a classical CPU—become superconductors that allow electrons to flow freely, scaling up the curious behavior of quantum mechanics to enable the computer to work. Microwave pulses are used to vibrate the qubits, and when two neighboring qubits reach the same frequency, they become entangled. This means that measuring the state of one tells you about the state of the other. Einstein famously poked fun at this idea, dismissing it as "spooky action at a distance," but since his death, it has been proved to be a real phenomenon.

QUANTUM SUPREMACY

There's another reason for keeping your computer cold, it blocks out the effects of the outside world. Noise is the great enemy of quantum computing, and noise-free, error-corrected qubits are its holy grail. That's not to say noisy qubits aren't useful for some things, Google was able to claim quantum supremacy (where a quantum computer solves a problem no classical computer could solve in a feasible amount of time) with its Sycamore chip in October 2019, even though its 54 qubits (it was meant to be 55, but one broke) aren't fully error-corrected.

Google claimed that its computer could perform a random sampling calculation, where it verifies that a list of numbers has been randomly generated, in three minutes and 20 seconds. This task would have taken IBM's Summit, the most powerful classical supercomputer, over 10,000 years.



A member of the Quantum Brilliance team doing something we're quite familiar with.

However, IBM disagreed and showed that, by changing the programming, Summit could have done it in 2.5 days. It was also pointed out that this was a contrived problem, with little real-world application, written to take advantage of the quantum processor's strengths. A 54-qubit quantum computer can't claim to be a universal one, like our PCs are—this could require anything up to a million qubits—so Google's claims are of a quantum advantage in particular calculations, rather than full supremacy.

Google, naturally, disagreed with this, arguing that as Sycamore was still faster, supremacy had been reached. "Sputnik didn't do much either," Hartmut Neven, manager of Google's Quantum Artificial Intelligence Lab, said during a press event. "It circled the Earth. Yet it was the start of the space age."

A group from The University of Science and Technology of China has also claimed supremacy, using a photonic quantum computer—one based on the properties of light, using photons and beam splitters to achieve quantum superpositions—to perform a Gaussian boson sampling on 76 photons in 200 seconds. This is a problem so complex it has been estimated a classical supercomputer would take half a billion years to do the same thing. The Chinese paper, *Quantum computational advantage using photons*, was published in the journal *Science* in December 2020. Again, this is not a calculation that's been begging to be solved to help with a real-world problem, but one that plays to the strengths of the quantum processor.

PRACTICAL USES & QUANTUM BRILLIANCE

So what can you do with a quantum computer right now? You could learn Qiskit, IBM's Python-based open-source SDK for working with quantum computers. Any algorithms you design in Qiskit can be run on either a quantum simulator or a real quantum computer accessible through the cloud, the idea is that

© QUANTUM BRILLIANCE

AND HERE...

people learn the basics of quantum computing models now, while the machines are in their prototype phases, before turning their knowledge loose on full-sized machines when they are available.

One machine that's about to come online is at the Pawsey Supercomputing Centre in Kensington, near Perth in Western Australia. Quantum Brilliance, a venture capital-backed offshoot from the Australian National University, has created a room-temperature quantum computer made from artificial diamonds and, compared with the supercooled giants being toted by the likes of Google and IBM, they're impressively small.

"Today, it is a 19-inch rack," says Dr Marcus Doherty, one of the co-founders of Quantum Brilliance, about the company's current two-qubit system. "Over the next five years, we'll be shrinking that into something the size of a GPU card, scaling up to about 50 qubits." That is impressively small, beating the previous record-holder, a trapped-ion computer using lots of lasers designed in Innsbruck, Austria, that squeezed 24 qubits into two server racks. There's that timescale again—not now, coming soon—though Quantum Brilliance would have had something in the wild by now (it was scheduled for installation in June) if it weren't for COVID-19. Once it's up and running, however, what will it do?

"It's a functional quantum computer, but its purpose isn't necessarily to solve the world's problems, rather its purpose is to allow people to integrate and learn how to integrate quantum computers into their classical computer systems, and learn how to really make it work. This will then inform future generations about quantum computers," says Doherty.

QUANTUM ADD-IN CARDS

The term 'GPU' comes up a lot in our conversation with Doherty, does he see a future 'QPU' becoming as common? "Different computing hardware is suited to different types of computational problems," he says. "Quantum computers offer advantages in certain problems that GPUs find difficult, so the future of computing is going to be a heterogeneous one, with different types of accelerators that cluster together to do different jobs. It's about using the best hardware to optimize particular applications."

In Doherty's case, that hardware is made from synthetic diamonds. Where others use extreme cold or a combination of lasers and magnetic fields to cut their qubits off from the rest of the universe, the rigid structure of diamond's carbon lattice does the job here. "We all know diamond is an extremely hard material," says Doherty, "and one outcome of being a very hard material is that, even at room temperature, there is not enough thermal energy to create significant vibrations in the diamond. And vibrations are the principal means by which qubits can decohere. And so because there is that much lower vibration, there's much lower decoherence, which means that we can observe and manipulate and operate our qubits at room temperature. Our style of processing is much more analogous to classical computing, in that you have qubits, you encode information on them, manipulate that information, and read it out."

There's slightly more than non-vibrating carbon atoms going on in those diamonds, however. "Our qubits are associated with nitrogen atoms, which live inside a thing called the nitrogen-vacancy center." Imagine a perfect diamond, with an all-carbon lattice, then replace one of the carbon atoms with a nitrogen atom. Simple, huh? This NV-center has a useful property: it's photoluminescent (it emits light when stimulated) and this allows physicists to read the spin-state of the atom. So, how do you do that? "Via the light," says Doherty. "The NV thing has a remarkable property: the amount of light that it emits depends on the spin state. It is brighter when it's in one state, and darker when in another state. This is just one of those wonders of nature."

Doherty's approach to quantum computing means taking these non-vibrating bits of diamond and then vibrating them a tiny bit: "We have to create an ultra-precise array of these NV centers in the diamond, so we have advanced fabrication techniques for creating the ingredients. Once they're in this array, we can manipulate them using microwaves and radio waves so they become entangled. And then we can manipulate that entanglement, to then process information."

ALL ABOUT TIMING

Another example of the timing problem quantum computing is suffering from comes from IBM's attempts to use a quantum computer to design new materials for batteries. Our current lithium cells are all well and good, but lithium mining, along with the extraction of the cadmium and nickel that also go into rechargeable batteries, takes a heavy toll on the environment and those who do the extraction.

IBM Quantum's Dr Gavin Jones, who has led much of IBM's research into battery chemistry, understated the matter somewhat, saying: "Quantum chemistry is complicated," in a webinar on IBM's YouTube channel. "There are many types of simulations we can perform," he says, "but quantum chemistry as practiced today on classical supercomputers struggles with many problems. This has mostly to do with the accuracy of the methods, and how easily we can carry out these simulations. For example, one of the most widely used methods is a density-

"Over the next five years, we'll be shrinking our current system into something the size of a GPU card and scaling up to about 50 qubits." **DR MARCUS DOHERTY**

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IBM engineers installing the System One quantum Computer at Germany's Fraunhofer Institute.

functional theory, but we have to carefully evaluate the accuracy of the methods by benchmarking, and this is time-consuming."

There's another problem with this kind of simulation: some don't reliably simulate particles with exotic or electronic properties, such as the radicals, biradicals, and unpaired electrons you find in batteries. "We like to use more accurate methods such as wave function methods to study the electronic structure of these types of systems," Jones continues, "but they can be very expensive in terms of the memory required and the amount of time required for the computation. We believe that quantum computers could help us perform the calculations more efficiently."

The general idea is that if you can simulate the interactions between all the electrons on the outside of atoms, how they bond with others when they react, then you can potentially create a new material that will have better properties than lithium, cobalt, or nickel when making the laptop batteries of the future.

Current quantum computers, at least the ones produced by IBM, aren't quite up to the job. "We have had some degree of success, but there's still work to do," says Jones in the webcast. "We've developed several error mitigation techniques such as noise extrapolations and also strategies to reduce the number of qubits required to simulate larger molecules, exploiting symmetry and frozen cores, active spaces for reactions," he adds.

They are also using hybrid simulations, run partly on classical computing hardware and partly on real quantum hardware, but the challenges include the development of better quantum algorithms as well as improvements to the hardware itself. "The main challenges are that we need to develop and use better quantum algorithms," says Jones. "Because we have a limited number of qubits, we're reliant on algorithms in which you run a quantum circuit hundreds, if not thousands, of times in order to perform statistics."

"At present, we can only perform calculations of small chemical systems, or study systems in which we limit the number of orbitals being used, to map onto fewer qubits," he adds. "In general, the development of better quantum hardware and error mitigation techniques, or fully fault-tolerant qubits, would help."

NOISY QUANTUM

Elsewhere at IBM, those things are under construction, partly as quantum simulators, that use classical computers to simulate the effects of quantum mechanics, and partly on real quantum computers. Quantum chemistry, the sort of simulations you need to do if you want to discover the properties of new materials for batteries or new drugs to treat diseases, means simulating the atoms in a molecule. "These are methods to solve the electronic structure," says Dr Ivano Tavernelli, global leader for advanced algorithms for quantum simulations at IBM's Zurich Research Laboratory. "So we present a molecule of water as one oxygen and two hydrogen atoms, then we want to know about the energy

QUANTUM 101

We have a man called Max Planck to blame for all this. His discovery of energy quanta—the idea that the heat or light coming off something is not a constant force, but a stream of little lumps—won him the Nobel Prize in 1918.

This threw open the whole discipline of quantum mechanics, in which you'll find names such as Bohr, Fermi, Schrodinger, Pauli, Heisenberg, and Einstein.

Indeed, Einstein won his Nobel Prize for the discovery of the photoelectric effect in 1921, rather than his more famous theories of relativity.

In the quantum world, particles behave both like points and little waves at the same time, with the magnitude of waves in any given region of space representing the probability of finding a particle at that location. Quantum computing relies on these strange properties of subatomic particles to do calculations in ways no classical computer could, using qubits instead of bits.

These qubits can be set at 1, 0, or both at the same time—known as a superposition—and often have to be cooled to temperatures close to absolute zero in order to work to minimize the effect of noise, or outside interference, on the calculation.

The whole field is in its infancy but performs best on algorithms specially designed for it.

Quantum supremacy, where a quantum computer demonstrates abilities that no classical computer can match, has been claimed, but not yet fully proven, and we're a long way from general-purpose quantum computers that can replace your PC.

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AND HERE...

of the system or the forces acting on the nuclei. To do that, you need to solve the Schrodinger equation [see boxout] and this can be done with classical computers but the cost rises exponentially with an increased number of electrons.

"What we are doing is to map this problem into a quantum computer, to solve a problem that is by nature quantum using a language that is also quantum by its nature. What we are doing at the moment is trying to optimize our algorithms to be able to execute the calculations on what we call near-term quantum computers—ones that have not yet been error corrected—so aren't fully fault-tolerant. Our goal is to show the potential for a quantum advantage using these kinds of machines before we get fault-tolerant machines."

A noisy quantum computer is still a useful one, it seems, but attempts to reduce the noise are ongoing. "There are two strategies," says Tavernelli. "One is to continue to improve the hardware and reduce the amount of noise in the qubits' operations as well as in the measurement of outcomes. The other is to apply error mitigation schemes, so we can make algorithmic corrections to the calculations we perform with noisy devices."

Tavernelli also has shocking news for those using two or 50-qubit machines, they will soon become obsolete. "At the moment, you will need roughly 1,000 physical qubits, noisy qubits, in order to make a single error-corrected, logical qubit," he says. IBM's roadmap is to learn what it can now, then try to set up such a device in the near future. "This will be reached in 2027, more or less. We will get to thousands of qubits, then the transition from noisy to fault-tolerant machines can begin," he says.

This sounds like a major threshold to cross, what will happen then? "If everything goes smoothly, our theory shows that these machines can correct all errors that will happen, so there are no limits. Even when quantum advantage is demonstrated, for many applications, it doesn't mean a quantum computer will completely substitute for a classical one, so you'll never get a [quantum] laptop, not during my lifetime. But there will be many applications where the quantum computer will significantly improve the predictions of graph discovery, fundamental physics, optimization, and machine learning. So you will be able to do things that are impossible even to think of nowadays because of the exponential scale."

IBM Quantum scientist Dr. Maika Takita in the Thomas J Watson Research Center IBM Quantum Lab

LIGHTSPEED PARTICLE SMASHING

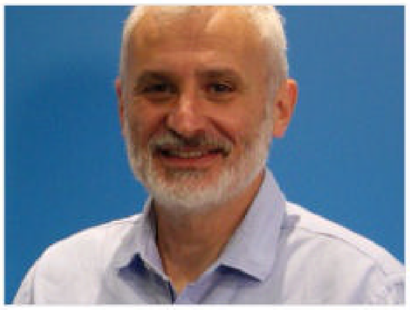
That scale means quantum computing could be used to process enormous data sets, such as that produced by the Large Hadron Collider. This particle accelerator, which exists as a giant ring 17 miles in circumference beneath the French-Swiss border, produces about 90 petabytes of data per year, and less than one percent of it ever gets looked at.

Tavernelli's colleague Dr Panagiotis Barkoutsos, also at IBM Zurich, is attempting to bring current quantum computers to bear on the problem. "The goal that's been set is that we want to find physics that can compete with or go beyond the standard model [*the theory that describes three of the four known fundamental forces that make up the universe, which currently doesn't include gravity*] and this is done by experiments in the Large Hadron Collider. The amount of data produced from an experiment is enormous, and the natural question is, can quantum computers help to process all this data more efficiently?

"We're not using words like advantage or supremacy because, in data, the quantum advantage is to have a meaningful simulation that's performed faster and better," says Barkoutsos. He and his colleagues have been testing it on old data associated with the production of the Higgs boson, one of CERN's greatest discoveries. This particle is associated with a fundamental field that gives other particles their mass. The more a particle interacts with the Higgs field, the heavier it is. The particle is a visible manifestation of the field, like a wave on the surface of the sea.

Through their work, IBM's researchers have shown that "quantum machine learning, in the context of vectors, can perform as well as its classical counterparts can perform," says Barkoutsos. "We're doing experiments out to 15 qubits, and we'll also use a 27-qubit device. The algorithms that we're currently

> "At the moment, you will need roughly 1,000 physical qubits, noisy qubits, in order to make a single error-corrected, logical qubit." **DR IVANO TAVERNELLI**



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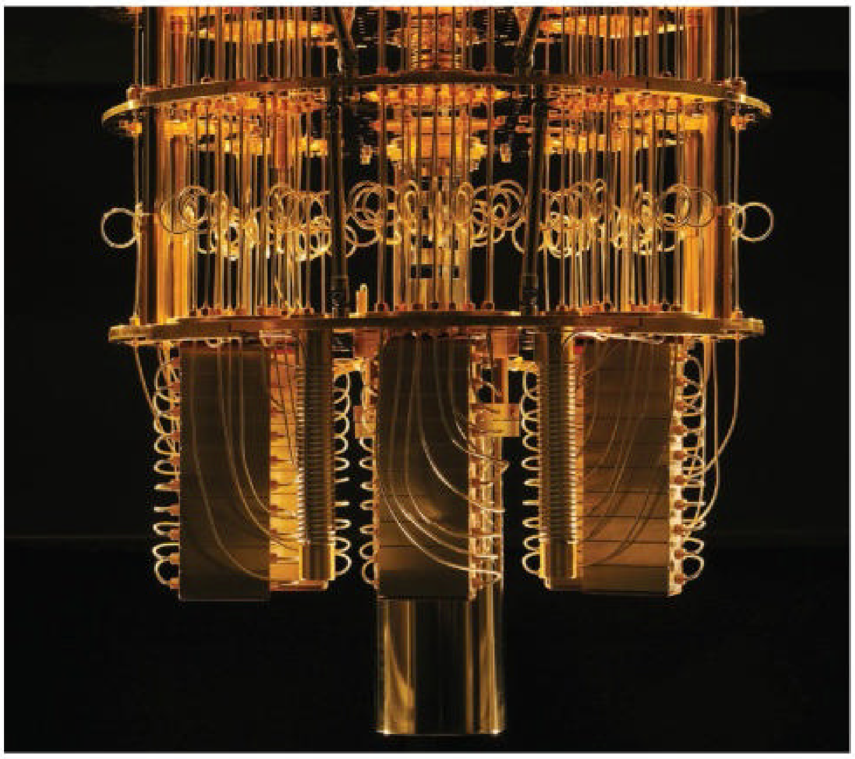

IBM's quantum dilution refrigerator, used to keep its quantum chips at a temperature colder than outer space.

developing are meant to be used on near-term computers, so if we had a fault-tolerant quantum computer, we would have to think in a different way. When fault-tolerant quantum computers exist, we'll be able to rethink the algorithms, and rethink the way that we are doing things to go beyond what we have already done."

IS IT POINTLESS?

Everyone we spoke to for this feature seems certain that the study of quantum computing will continue, and will eventually succeed. Others, however, have voiced concerns that the noise problem may never be overcome, a fully fault-tolerant quantum computer may never be built, and the computers that exist today aren't really all they're cracked up to be. In the words of Isaac Chuang of the Massachusetts Institute of Technology, "Quantum computing today is actually, from a practical standpoint, quite useless, other than for generating publicity."

A *New Scientist* article from August this year contained not only the above quotation from Chuang but also contributions from two other professors. Gil Kalai, a mathematician at Israel's Hebrew University of Jerusalem, said: "My analysis asserts that quality error correction won't be possible."

Meanwhile, Sabrina Maniscalco at the University of Helsinki in Finland is of the opinion that: "Finding a remedy to the effect of noise induced by the environment is not just... a technological issue, but more of a conceptual and foundational one. I would say that I am hopeful, rather than confident."

"What if I told you that there is no law of physics that tells us that we cannot go beyond this noise problem?" says IBM's Tavernelli. "There's nothing proven that tells us that we will not be able to go to fault tolerance. It is a difficult mission, that much is clear. So we may need to go slow, we may need to do things in a manner that is difficult to do in an experiment, but still, no law tells us we are not going to be able to go beyond the noise problem."

Tavernelli certainly sounds more positive than some of his counterparts. "Although there is no law, I don't believe we will ever be able to have one single physical qubit standing without noise," he says, "For this reason, there are correction schemes that tell you we are going to have physical qubits that can be mapped into a logical qubit, and we're going to have more advanced error correction schemes that tell us we're going to connect different physical qubits one with the other, to create a logical qubit that's self-correcting through the error correction schemes," he explains. "There may be an overhead in the number of qubits that are required for the generation of a single logical qubit, but still, you're going to get one unit of information that's going to be self-correcting," Tavernelli concludes.

Doherty foresees other problems. "The great advantage of quantum computing is that for a fewer number of resources, you can manipulate larger amounts of information more efficiently," he says. "That's because you can encode more information onto fewer resources. That ability to encode more, and to manipulate more, stems from two physical properties. The first is quantum superposition, which people often describe as being in two places at once, and the other is entanglement, which is Einstein's famous paradox, where you can have two things correlated with one another that are not necessarily near each other. You must be able to entangle qubits in order to get the full advantages of quantum computing," Doherty adds.

"Then there's a big but: you can't get all the information out at once. You can only ever get out a certain amount, and that's the devil of quantum mechanics. What it means is that, unlike a classical computer, where you can read the information in its entirety, in a quantum computer, you can only sample the information and get some of it out. So this means that quantum computers are probabilistic and statistical. The art of making quantum algorithms—which isn't easy, and we, the big 'we', don't know how to do that well at the moment—is to create something

"Quantum machine learning, in the context of vectors, can perform as well as its classical counterparts can."

DR PANAGIOTIS BARKOUTSOS

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AND HERE...

where you can manipulate the information efficiently, but also collapse it in a way that you can get it out efficiently, which is often the hardest thing."

COMMERCIAL APPLICATION

And while Tavernelli doesn't think you'll see a quantum laptop, IBM is spreading its quantum computers across the world, with the installation of the IBM Quantum System One at Germany's Fraunhofer Institute, a research organization focused on applied science, i.e. actually making stuff. The System One contains a 27-qubit Falcon superconducting processor and will be used to "solve major business and societal problems," according to the institute's press release.

Quantum computers right now are much like the System One, following the supercomputing model of accessing them via classical computers, networking them to allow multiple points of entry, and using that expensive processing time efficiently.

Doherty imagines quantum data centers and even quantum robots. "In principle, our quantum computers can be everywhere," he says. "We believe there's a variety of important applications in robotics, autonomous systems, and space systems. We're increasingly seeing autonomous, robotic, systems encroach on our everyday lives for work and entertainment, and they rely more and more on things like AI and machine learning. So we may see quantum computers in our homes to support those sorts of computing requirements."

Just what is it about AI workloads that makes them so suitable for quantum processing? It seems a world away from simulating electrons. Doherty explains: "Depending on how you construct your workflow with AI, there are sometimes cases where you may be processing an image or a video, or you might be listening to a person's voice, and you've got to predict what will happen and in what order. Machine learning is very exact at extracting and guessing what is happening in each moment in time, but classical computers find it very difficult to go 'what's the most likely sequence of events?' But a quantum computer is quite adept at doing things like determining the most likely sequence of things actually happening.

There are plenty of new developments and breakthroughs in quantum computing. In August 2021, Japan's Riken Center for Emergent Matter Science announced that it had demonstrated a triple-qubit silicon-based system that shows entanglement is possible across three qubits, making things like error correction and scaling up the number of qubits easier. Earlier, researchers at another Australian outfit, the UNSW School of Electrical Engineering and Telecommunications, demonstrated control of quantum spin qubits by using a crystal prism—something that could potentially be scaled up to control millions of qubits at once.

Research by The Quantum Insider predicts that the market for Quantum computing as a service will hit $4 billion by 2025 and $26 billion by 2030 and, despite the note of caution sounded by some academics that the discipline is a bit of a dead-end, we're going to see a lot more of this technology—whether accessed through the cloud, sitting in a data center, or even a GPU-sized card controlling your house robot or self-driving car. It looks as though Quantum computing is here to stay.

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SCHRODINGER'S EQUATION IS DEAD AND ALIVE

Perhaps better known in popular culture for his cat, Erwin Schrodinger (pictured) was a Nobel Prize-winning physicist who was in at the beginning of quantum theory. His equation acts as quantum mechanics' equivalent of Newton's second law—the one that goes force = mass x acceleration.

Newton's law predicts how a physical system will move over time, and so Schrodinger's equation does the same for an isolated quantum system. Given a known set of initial conditions, it can predict the evolution of the wave function of a system, making it useful in quantum chemistry.

Schrodinger's Cat is a thought experiment, please don't try to carry it out, you'll only end up with an unhappy cat and possibly some unwanted attention from the FBI. He came up with the idea during a discussion with Einstein, in an attempt to point out what he saw as problems with quantum mechanics.

It goes like this. You have a box from which no radiation can escape. In the box, you place a cat (although any small mammal would do), a vial of poison gas, and a lump of unspecified nuclear material. The chance that the nuclear material will release a particle that will penetrate the vial, release the gas, and kill the cat is about 50/50. Once you seal up the box, you have no way of knowing (it's a very docile cat, apparently) what has happened until you open it and observe the state of the system. Therefore, while the box is closed, the cat can be said to be in a superposition—both alive and dead at the same time.

This was intended to poke fun at the Copenhagen interpretation of quantum physics, the prevailing view at the time—if the cat survives, it remembers nothing of being dead, so at which point did this superposition happen? These days, it's arguably more famous than its author, thanks to its inclusion in novels, poetry, TV, games, and movies.

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ULTRA-MOBILE COMPUTERS & YOU

From subnotebooks to Ultra Mobile PCs, these machines have come and gone over the years. **John Knight** asks if we are about to see their return.

WHATEVER YOU WANT to call these things, in this feature we'll be exploring the history of the ultimate in tiny computers—not including the now-ubiquitous smartphone. We'll start with early and ground-breaking models in the 1980s, through to the more mature models in the '90s. We'll also take a look at the UMPC craze of the 2000s and the wilderness years that followed, and dive deep into the resurrection of this form currently taking place in China, examining the models that are on the market today and where they're going in the future.

So how do you classify these computers? Well, to pull some rules out of nowhere, we're going to define these as something that can fit ideally in your pocket; has some kind of integrated keyboard; and something that has a screen that comes in under 9-inches, at a stretch, though less than eight would be ideal.

For simplicity's sake, we also need to establish what to call these things too. We've decided to settle on "pocket computers" for smaller machines, and "ultra-portable" for the bigger offerings, though it's worth pointing out these are pretty interchangeable terms, too.

Of the many super-small computers out there, we've had to whittle down the choices to just a select few – sadly, there are only so many small machines we can cover, but hopefully it's enough to give you a flavor of the ultra-portable history. If there are any machines you particularly wanted to see, write in and let us know.

THE BEGINNING OF POCKET COMPUTERS

DEFINING THE FIRST pocket computer is difficult due to the popularity of electronic organizers in the 1980s. Nevertheless, the title of first real pocket computer is generally awarded to Radioshack's TRS-80 Pocket Computer (aka. Tandy Pocket Computer), so let's start there.

INFANCY

The TRS-80 Pocket Computer was launched in July 1980, for $249. Despite the American branding, this machine is actually a re-badged Sharp PC-1211 from Japan.

This 6oz (170g) handheld may look like a normal scientific calculator, but it also packed a QWERTY keyboard, 1.5KB of RAM, and two 4-bit CPUs running at 256KHz. Most importantly, it included Sharp BASIC, making it the first genuine pocket computer.

But this is a far cry from a x86 "IBM-Compatible" PC. For that title we need to turn our attention to the DIP Pocket PC—better known as the Atari Portfolio. Released in June 1989, the DIP Pocket PC was the first PC-compatible pocket computer, manufactured by DIP Research, UK. DIP's machine caught the eye of American computing giants Atari, who re-badged the machine as the Atari Portfolio, or Atari PC Folio in continental Europe.

Sporting a 4.9MHz 80C88 processor, the $400 Portfolio had 128KB of RAM, half of which was used for system memory, the other half for user storage. Housed in the Portfolio's 256KB ROM chip was DIP DOS 2.11: an MS-DOS compatible DOS clone from DIP Research. The unit measured only 7.5 x 4 x 1.25in, and the lack of an LCD backlight, hard disk, or internal floppy drive allowed for excellent power efficiency, requiring only three AA batteries to operate.

But 128KB split two ways is a tiny amount of memory and storage, so Atari sold RAM extenders, plus other add-ons such as serial data transfer modules, and software ROM cards. The weird 240x64 pixel display means there aren't many games for this machine. None of these drawbacks matter, because the Atari Portfolio is a film star, ever since its famous cameo in *Terminator 2*.

In October 1989, the Poqet PC was launched by the Poqet Computer Corporation. Of all the machines here, the Poqet PC is probably the most technically impressive for its time, but at $2000 (around $4000 in today's money) it should have been.

The Poqet's stylish red-on-charcoal case is a bit wide at 8.8 x 4.3 x 1in, but it uses that space perfectly with an excellent keyboard. Powering the machine was an Intel 80C88 processor @ 7MHz, with between 512 and 640KB of RAM. CGA-compatible graphics were run through a non-backlit monochrome display. MS-DOS 3.3 was built into ROM, with an internal 22KB RAM drive.

The Poqet was designed around PCMCIA expansion, helping establish the standard by being one of the first machines to use it. Two slots were provided, one on each side, and special Poqet software was released on ROM cards.

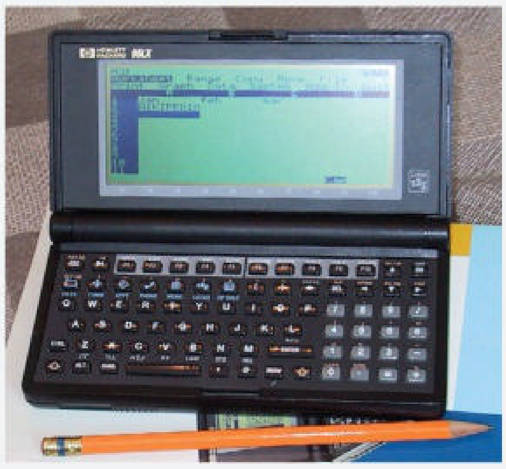
HOW CAN I STILL USE THESE THINGS?

For anyone still using these computers, the main task is usually writing. They provide simple text editing, without the clutter and noise of a modern OS. Some use their old-fashioned Lotus spreadsheets, or as Linux dumb terminals.

Some of the more powerful devices here can be a way to play DOS games, or use OS/2 or Windows 3.x (or Windows 9.x with later machines) on real hardware. Of course, copying files between these machines and modern computers can be a challenge.

If your old computer has a PCMCIA slot, you're in luck: there are plenty of cheap adapters online for using Compact Flash or SD cards as a replacement hard drive.

Simply remove the card when you're not using it, then plug it into a modern PC.



Hewlett Packard's HP 95LX got the design just right, with excellent battery life, plenty of features, and a low price.

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The Poqet runs on just two AA batteries, which is all it needed due to pioneering energy-saving techniques. Battery life is between 50 and 100 hours, which would last most users weeks or even months.

CONFIDENT YOUTH

In 1991, Hewlett Packard released the HP 95LX Palmtop. While not as technically impressive as the Poqet PC, at $700 it was far cheaper.

This well-packaged pocket computer brought mobile computing to the masses. Touted as a "PC XT in your pocket", the 95LX came with both MS-DOS 3.22 and office suite Lotus 1-2-3 built into ROM.

Rather than an Intel 8088 processor, the 95LX used an NEC V20 clone @ 5.37MHz and came with either 512KB or 1MB of RAM. The 95LX was truly portable, weighing just 11oz (312g) and measuring 6.5 x 3.5 x 1in. Two AA batteries provided around 30 hours of running time. The 95LX used SRAM storage, with a maximum card size of 32MB.

Despite the impressive packaging, it was an add-on that truly immortalized the 95LX. The Motorola NewsStream slide-on attachment would connect to a wireless online database, allowing access to email, spreadsheets, and news services—all without a phone or modem.

A weakness was the 95LX's display, which was non-backlight, monochrome, and only allowed for a 240x128 "quarter CGA" resolution. This meant many graphical programs simply couldn't display on its hardware. These problems were later addressed with the HP 100LX (1993) and 200LX (1994) which came with more RAM – 1 or 2MB respectively – and a 640x200 display. Coupled with MS-DOS 5.0, these machines could even run Windows 3.x.

MATURITY

In the 1990s, the Rolls-Royce of ultra-portables was the Toshiba Libretto range, designed to fit a full Windows PC into the dimensions of a paperback novel. Toshiba products have always been beautifully made, and the Libretto range was no exception. Launched in April 1996, the Libretto 20 measured 8.2 x 4.5 x 1.3in, powered by an AMD 486 DX4 CPU @ 75MHz, with 8MB of RAM (upgradeable to 20MB), a 270MB hard drive, and a 6.1in TFT display. Floppy and CD-ROM drive access were available through PCMCIA expansion. Battery life was two hours.

The Libretto has a quirky mouse input method: an IBM-style "nub" is located on the right screen bezel, while the mouse buttons are on the top side of the lid—your thumb controls the pointer, your fingers click the buttons. These machines weren't cheap, however, with prices starting around $2000, and the first models originally only sold in Japan.

The Libretto packs quite a punch but isn't perfect. Most owners complain about its slow and noisy mechanical hard disk, and while it has a keyboard, it isn't for the fat-fingered. Nevertheless, Librettos are quickly establishing themselves as great portable gaming PCs with retro enthusiasts, and those nasty hard disks can be changed for a compact flash card with a simple adapter.

The original ultra-portable Libretto range continued to be upgraded until it was discontinued in Europe and the US in 1999, and in Japan in 2001.

PALM OS PDAS

If you said "palmtop" in the '90s, these are the machines that came to mind: Portable Digital Assistants (PDAs), most of which were powered by Palm OS.

These devices sat somewhere between proper computers and simple electronic organizers. Instead of a small keyboard, these Palm OS devices mainly used stylus input, with users required to learn the Graffiti handwriting recognition system. Data was transferred between your PDA and PC with a sync-cable or infra-red adapters.

While Palm OS devices usually came with only a collection of basic office utilities, several megabytes of storage allowed users to add downloaded games to their devices. These games ranged from simple *Minesweeper* clones to something more advanced such as *Sim City*, all the way up to *Doom II*, as seen on the Tapwave Zodiac gaming handheld (2003).

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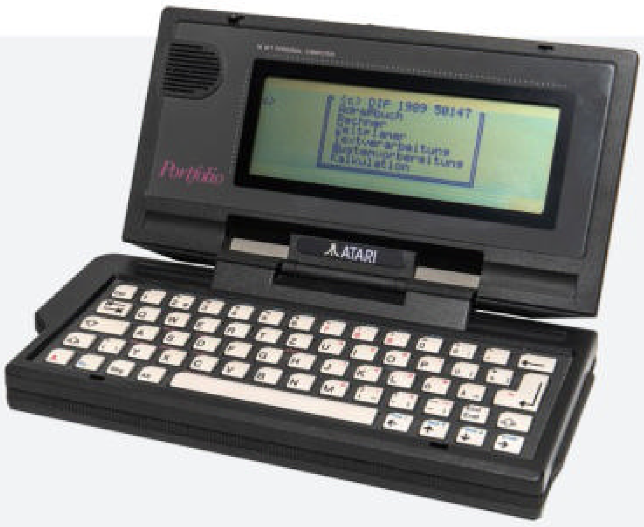
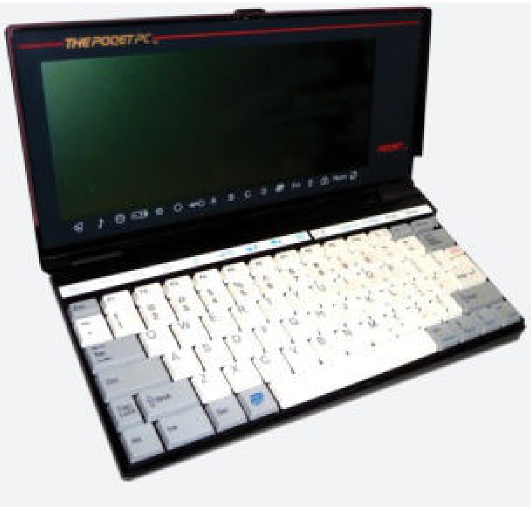
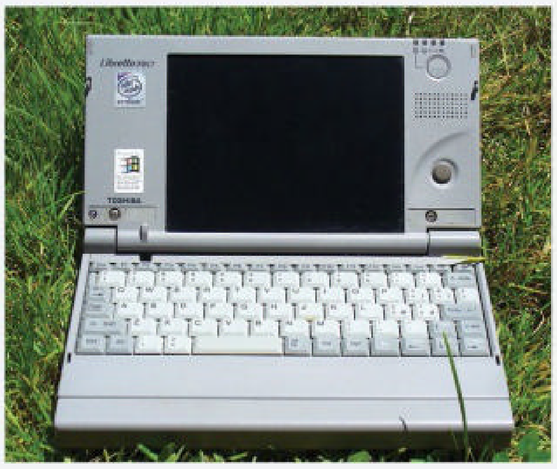
Palm started the millennium with a bright future and a strong market, but its devices (and PDAs in general) became more redundant with each advance in smartphone technology. HP bought out Palm in 2010 after the company developed its new webOS but then threw in the towel after poor sales.



Despite the Atari Portfolio's technical abilities, it will always be associated with John Connor hacking an ATM in *Terminator 2*.



The Poqet PC's design meant users rarely sat through boot sequences, and office tools were available via a simple hotkey.



Toshiba's Libretto series was initially made for Japan only, but was later sold internationally after wowing consumers.

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BEYOND 2000 THE WILDERNESS YEARS AND THE UMPC WAVE

MINIATURE LAPTOPS started dying out after the new millennium. Windows CE was becoming the de facto standard for portable computers, providing all the quirks of a PC without the benefits of a x86 ecosystem. In the early 2000s, Microsoft made a failed attempt at introducing a tablet PC standard, including its much-maligned Windows XP Tablet PC Edition. Undeterred, Microsoft would see success in the mid-2000s with a new design standard.

THE UMPC STANDARD

In 2006, Microsoft released the UMPC standard, or "Ultra-Mobile PC". This specified a screen of eight inches or less, with a minimum resolution of 800x400. Screens were to be touch-sensitive, and many UMPCs used stylus input. In preparation for the new machines, Microsoft made minor tweaks to Windows XP to make it more usable with small screens and touch inputs.

One of the first UMPCs released was the Samsung Q1. Launched mid-2006, the Q1 featured a 7-inch touchscreen with a small-key thumb keyboard split in two, with each half on either side of the screen.

Inside the quirky new tablet was a 900MHz Intel Celeron and 512MB of RAM, plus Wi-Fi, Bluetooth, an ethernet plug, and two USB ports. All respectable for the time, other than the 4200RPM mechanical hard drive. However, of the many UMPC variants, the two most important machines were probably the Sony Vaio UX series, and the OQO Model 02.

DAVID AND GOLIATH

Sony had a head start in 2004 with its U series of PDAs, but these lacked an integrated keyboard. For the new UMPC standard, Sony's Vaio UX Micro PC came with a small keyboard tucked behind a sliding screen. Primary buttons and controls were on either side of the 4.3-inch screen, with a rubber nub for mouse control that was used with the right thumb.

Ground-breaking for its time, it included a front-facing camera, fingerprint reader, Wi-Fi, and SIM slot. Powering the Sony was a choice of Intel Core or Core 2 Solo processors, with 512MB or 1GB of RAM, and between 16-100GB of storage.

Competing against the Japanese giant was American manufacturer OQO. Despite its niche position, OQO received a huge market boost when Bill Gates introduced its Model 02 at 2007's Consumer Electronics Show.

Previous OQO models were already close to Microsoft's standard, but the Model 02 brought OQO up to spec with stylus input and Wi-Fi. The Model 02 also had a slide-out keyboard hidden behind its screen, as well as a nub-controller and mouse buttons.

Powering the OQO was a 1.6 GHz VIA C7-M ULV processor, 1 GB of RAM, and 64 or 120 GB of storage. The Model 02 also had a SIM slot, and although it didn't include a camera or fingerprint reader, it had a bigger display, a better battery, and HDMI output.

Both brands had a choice of mechanical or solid-state hard drives. The mechanical hard drives were diabolical. The tiny keyboards didn't win many fans either, but the OQO had a nice amount of key travel, whereas the Sony keyboard lacks any feedback. The Sony is let down by its 2-3 hour battery life, while the OQO is let down by its underwhelming VIA processor.

Despite these flaws, both models were hugely popular. The OQO Model 02 won a raft of industry awards, while the Sony Vaio UX series

USING THESE THINGS PT 2

While it may be handy to keep a running version of Windows XP for old proprietary software, these machines could be ideal candidates for lightweight modern operating systems, such as "lite" Linux distributions, BSD variants, AROS, or Haiku.

For those willing to dig inside their machines, a modern SSD or IDE to SD-card adapter could provide an upgrade for anything lumbered with a mechanical hard drive. Other than increased reliability, these modern replacements should provide improvements to both performance and battery life.

The mechanical hard drive was the Sony Vaio UX's Achilles' heel, but a retrofitted SSD makes a great restoration project.

Samsung's Q1 UMPC helped pioneer this two part thumb-keyboard design. Thankfully, it wasn't a design that lasted!

OQO's Model 02 was a beautiful piece of engineering. In a just world OQO would still exist, but it ceased operations in 2009.

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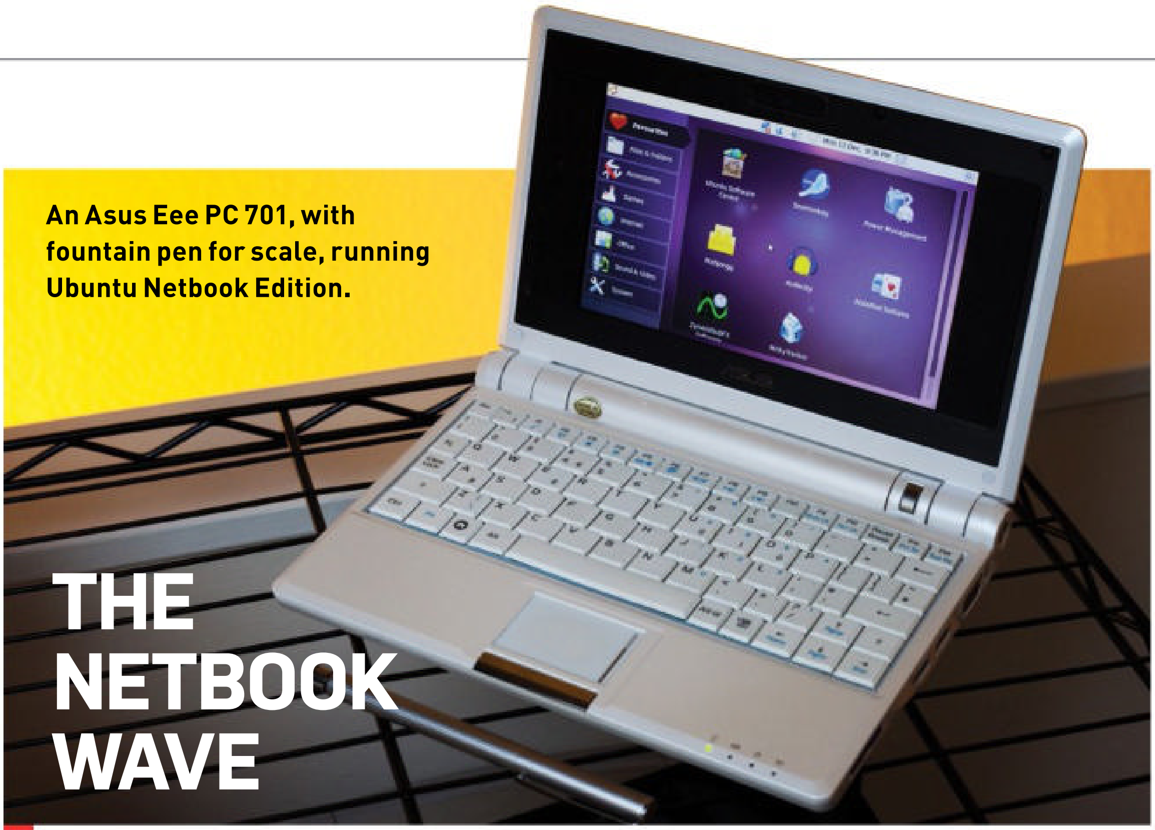

An Asus Eee PC 701, with fountain pen for scale, running Ubuntu Netbook Edition.

THE NETBOOK WAVE

Most netbooks are too big to be called ultra-portable but are usually the first thing people mention when asked about tiny computers.

While numerous products could claim to be the first netbook, the Asus Eee PC in 2007 kickstarted the category. The Eee PC was nine inches wide, with a 7-inch display and a decent keyboard. Costs and power consumption were cut by removing optical drives, and early models shipped with a custom version of Xandros Linux and a 4GB SSD.

Response to the Eee PC was overwhelming, spawning many rivals, but most netbooks from this point shipped with standard mechanical hard drives and Windows XP. Most grew in size to between 10 and 14-inches.

Netbooks were most popular with students: they fit easily into a backpack and could be typed on well enough for assignments.

Netbooks stole a sizeable market share from both laptops and pocket computers and were popular for several years. However, most had awful Intel Atom processors, which were incapable of running Vista or Windows 7.

While netbooks are still available, their market share has been lost to Chromebooks and tablets.

became a film star, featuring in such movies as *Terminator Salvation*, *National Treasure*, *Casino Royale*, and *Quantum of Solace* – there was even a special 007 edition!

A DYING BREED

Unfortunately, the UMPC craze didn't last, as people turned to netbooks and smartphones. Nevertheless, there were some standout models in the UMPC's waning years. Starting with the Fujitsu LifeBook series, models such as the U810 (2007-08) and UH900 (2010) formed part of the second generation of UMPCs with much-improved specifications. The U810 is a particular standout, with twice the battery life of first-generation UMPCs.

The Pandora was a marvel of open-source philosophies and innovative design, but will we ever see its sequel?

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Our favorite machine from this time is probably the HTC Shift X9000 (2008). The Shift used a unique slide-and-tilt mechanism that brings its keyboard out from behind a 7-inch display, resulting in something that looks and functions like a clamshell laptop but folds away flat for storage, or that can be used as a tablet.

Under the hood is an 800-MHz Intel A110 processor, with Intel 945 graphics, and 1GB of RAM. This was just enough to run Vista at the time, but many people ditched Vista and "downgraded" to XP. This provided a much faster experience and a decent gaming platform for anything from the XP era and earlier.

NON-PC PORTABLES

As the 2010s advanced, UMPCs died out and netbooks weren't far behind. The iPad popularized tablets and everyone had smartphones—those still using PCs reverted to traditional laptops and desktops.

In the non-x86 world, things were different. In 2012, the Raspberry Pi shook up hobbyist computing, spawning new cottage industries. Unlike the x86 world, which was dominated by Windows, these new machines ran ARM processors. And in ARM world, Linux was king.

The Pi's minuscule proportions could be crammed into tiny spaces, spawning countless designs, including new pocket-sized laptops, such as the LapPi, Nano Pi2 UMPC, Adafruit Mini Handheld Notebook, LEGO Raspberry PiBook, and the imaginatively titled "Raspberry Pi & Arduino Laptop".

Beyond the Raspberry Pi scene, 2016's PocketCHIP provided ultra-cheap thrills. Based on the $9 CHIP computer, and retailing for $69, the system uses a keyboard design similar to a Sinclair ZX81, matched with a 4.3in color LCD. The system is hackable as it runs on a regular version of ARM Debian. A D-pad is included for gaming emulation, with 5-8 hours of battery life.

However, if we go back in time even before the Raspberry Pi, there was one brilliant machine: the Pandora. Released in May 2010 by OpenPandora, the Pandora is like a cross between an HP 95LX and a Nintendo DS. Somehow its tiny pocket-sized clamshell design managed to fit a QWERTY keyboard, dual analog sticks, face buttons, and even a D-pad, with a 4.3-inch monitor.

Two SD slots, a headphone jack, and multiple types of USB port allowed for easy expansion, while the battery gives 10 hours of realistic running time or 20 hours of economical use. Standby lasts a week.

Powering the machine is a 600 MHz Texas Instruments OMAP3530 CPU, with PowerVR SGX graphics, and 256 MB of RAM. Not exactly a computing powerhouse, but it didn't need to be. For the operating system, the Pandora provided two lightweight Linux distributions based on the Debian ARM repository.

Unfortunately, the production run was limited, so these unicorns are guarded jealously by their owners. If you ever see one for sale, snap it up.

THE SHENZHEN REVIVAL

ALTHOUGH TRADITIONAL manufacturing giants have largely abandoned pocket computers, the format has seen a renaissance via boutique manufacturers from Shenzhen in China. These companies have avoided the pitfalls of traditional product development by crowdfunding and skipping normal retailers in favor of online stores such as AliExpress, Amazon, and eBay.

Of all the boutique makers, GamePad Digital, or GPD, is one that can truly be called a trendsetter. GPD has developed a cult following redesigning neglected forms into something truly desirable.

GPD

GPD first caught the world's attention in 2015 with the XD: an ARM-based Android gaming device, designed for easy emulation and styled like a Nintendo DS. It was an instant hit among retro gaming fans, due to its simple design, clever tweaks, and generous expansion.

Following the XD's success was the GPD Win: a Windows 10 handheld with console controls. After moderate success with the Win, GPD stepped away from gaming to make something very different: the Pocket.

THE POCKET MILESTONE

The GPD Pocket reinvented the discarded netbook format by shrinking the design to a mere seven inches overall. Despite its diminutive size, clever engineering compromises allowed for a keyboard that was reasonable for typing on, encased in a sturdy aluminum chassis. Customers could choose between either Windows 10 or Ubuntu pre-installed.

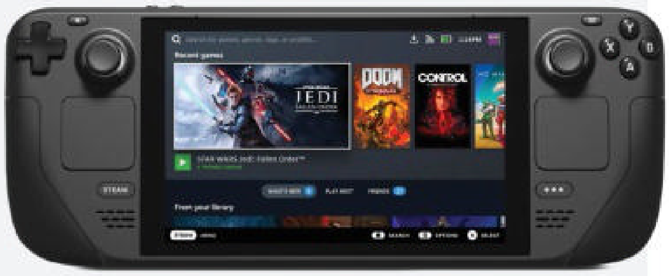
The Pocket was a runaway success, and in 2018, GPD released the Pocket 2, which added a more powerful Intel Celeron CPU and swapped the "nub" mouse for an optical touch sensor. While GPD's earlier products were designed around gaming, the Pocket was a hit with writers and students, who wanted to work anywhere, any time, with a product that was truly compact and portable.

Its design hit a sweet spot that spawned numerous imitations from Shenzhen rivals, such as One-Netbook's One Mix Yoga series (2018), which has a 360-degree hinge and stylus support; and the Chuwi Minibook (2019), which also has a webcam, and a cheaper price.

Interest in the GPD Pocket led to other niche products, such as the MicroPC—a cheaper, ruggedized handheld for engineers with an RS-232 port; and the P2 Max, a tricked-out 8.9-inch netbook GPD has dubbed 'the world's smallest ultrabook'.

GPD is still selling the Pocket 2, while One-Netbook's line has morphed into the OneMix series. You may still be able to find the older 7-inch OneMix2 for sale online, while the OneMix3 stretches to an 8.4-inch screen, and the OneMix4 is a full 10.1-inch netbook.

The GPD Pocket combines UMPC and netbook design elements into something better than either format.



Valve's Steam Deck is too big for this category and has a virtual keyboard, so no good for writing articles on it.

WHAT ABOUT GAMING?

For many years, companies have tried to make something ultra-portable and capable of modern gaming. However, the mobile processors needed by such small machines have always been a generation behind desktop PCs. But now it seems we finally have the right technology.

In 2016, GPD launched the Win, with an intel-based Windows 10 touchscreen handheld. Although its QWERTY keyboard couldn't be used for proper typing, its design allowed dual analog stick controls, face and shoulder buttons, and a D-pad.

The Win was a reasonable success and was followed in 2018 by the Win 2, which upped the screen size from 5.5 to 6-inches, ditched the lousy Atom processor for an Intel Core m3, and doubled its RAM from 4 to 8GB.

While these machines were great for indie gaming and emulation, they were unrealistic for modern AAA gaming, and their keyboards were too small for proper typing. But in 2021, the Win 3 was launched, and it's a far more compelling games machine.

The design has changed, with GPD ditching the clamshell design for something resembling a Nintendo Switch, but slide the screen upwards and it reveals a keyboard, like an old Sony Vaio. The touchscreen is 5.5in, with an overall footprint of 7.8in.

The Win 3 is powered by the Intel Tiger Lake platform, sporting a 4.2 GHz Intel Core I5-1135G7 CPU and a

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Shenzhen is often referred to as “China’s Silicon Valley”

WHY SHENZHEN?

Shenzhen is often dubbed “China’s Silicon Valley”, with a techno culture unlike anywhere in the world. What would normally take months of development in the West takes weeks in Shenzhen. Rather than supplying traditional brick-and-mortar stores, most companies sell online.

Huge bazaars of electronic components allow developers instant access to the parts they require. Need an arcade button? Then simply go to the stall selling buttons. Need an analog stick? There’s probably a stall for that too.

In Shenzhen, it’s not uncommon to see people rummaging through bins, however, they’re looking for old phones to salvage parts, rather than searching for food.

This hyper-availability of parts has created a market of niche gadgets where anything gets made. Ideas are copied (or stolen) and improved upon. Open-source software and hardware are popular, with Linux and Android powering most gadgets.

Gen12 Iris Xe GPU. There is now 1TB of NVMe M.2 SSD storage and 16GB of RAM. All this allows for a viable gaming experience, even if it won't rival desktops. GPD even provides a customized image of Ubuntu MATE for Linux users. On the downside, its small, flat keyboard has not been well received, as it gives bad feedback and appears to have reliability issues.

There is competition in Shenzhen and, for those who prefer team AMD, there is the Aya Neo, which packs a 4GHz AMD Ryzen 5 4500U APU and a 7in touchscreen. For an Intel rival, there is the bulkier OneXPlayer Handheld PC, with a 4.8GHz Intel Core i7 1165G7 CPU, Intel Iris Xe 96 EU GPU, and an 8.4-inch touchscreen.

However, neither the Neo nor the OneXPlayer has physical keyboards: you use an on-screen virtual keyboard, so neither fits our specification for an ultra-mobile PC.

The GPD Win 3 and OneXPlayer Handheld PC are available at online stores such as AliExpress and Amazon, while the Neo is available from Aya's website.

BUT I WANT A PROPER KEYBOARD!

If none of these options take your fancy, there are gaming machines that retain a clamshell design, but add game controller features. The first is One-Netbook's OneGx1 (2020). During normal operation, it looks like a small netbook, but has RGB lighting and a rear cooling design "borrowed" from Alienware gaming laptops and is transformed by two controller paddles that attach either side.

Reviews are mixed. Some love it, others find it flawed and impractical. The 7-inch screen has stylus support, and the machine has an overall footprint of 8.4-inches without paddles. It is older than other models here, with a tenth-generation i5 core processor that maxes out at 4GHz.

The last machine to consider is the GPD Win Max. This essentially enlarges the older Win 2 design with a proper typing keyboard and places the touchpad, control sticks, and buttons above the keyboard.

While it started life in 2020 with the same family of Intel CPU as the OneGx1, the new 2021 model comes in two varieties: a quad-core 11th Gen Intel i7-1195G7 CPU (5Ghz maximum), or an eight-core 4.2GHz AMD Ryzen 7 4800U APU.

The Win Max has an 8in touchscreen, 16GB of RAM, and 1TB of M.2 SSD storage. Reviews have been positive, and both the Win Max and OneGx1 have excellent I/O expansion. Both are available on sites such as AliExpress and Amazon.

ONLINE PRICES*

GPD Pocket 2	$625 – $900
GPD MicroPC	$433 – $640
GPD P2 Max	$800 – $1200
One-Netbook OneMix3	$800 – $1670
GPD Win 3	$1100 – $1550
Aya Neo	$1015
OneXPlayer Handheld PC	$1000 – $1600
One-Netbook OneGx1	$1100 – $1500
GPD Win Max	$2100

* THESE WERE THE APPROXIMATE PRICE RANGES OF EACH MODEL AT THE TIME OF WRITING, DEPENDING ON SPECIFICATION.

CENTERFOLD

PERFORMANCE GEAR LAID BARE

The Modded Monster

WHEN INTEL ASKS YOU to build the ultimate dual system for its Gamer Days campaign, it's hard to say no. Especially when what you create is being given away to one lucky winner. The best part is yet to come, though. By entering to win* this insane system, you will truly be helping a great cause.

Technovation is an incredible non-profit organization that empowers girls and young women to become leaders through tech education. The Technovation Girls program equips women (ages 8-18) with the support of volunteer mentors and parents. Technovation Girls work in teams to code mobile apps that address real-world problems. No pressure then.

To enter the sweepstake, simply donate $10 or more by visiting prizeo.com/mod83. If you want to give more, you'll earn more entries to win. You can use the promo code "MOD83" and get 200 bonus entries when you make a donation too.

Make dreams come true for young girls around the world, and maybe your own, by being the lucky winner of this epic build. And, we'll give you the lowdown on the world of PC modding, including this bad boy, in the next issue. **–KRIS BUTTERILL**

1 SPECIFICATION

No expense has been spared in building this ultimate dual gaming system. Featuring both a flagship Intel i9 11900K and its sibling, the Intel i7 11700K, the heart of this machine is smothered in ASUS goodness.

A ROG Maximus XIII Extreme Glacial and ROG Maximus XIII Hero provide both Z590 platforms, while the ASUS TUF RTX 3090 and ASUS TUF RTX 3080 supply as many frames as you can throw at it. Add in 64GB and 32GB of Corsair Dominator DDR4 respectively, 10TB total NVME storage by WD Black, full hand-crafted Alphacool cooling loops, and much more!

2 PERFORMANCE

Never worry about playing the latest gaming titles in glorious 4K while also rendering your latest social media sensation. Sit back, relax and let the hardware do the talking, knowing that whatever you throw at this monster, there will be room to spare, and then some.

Worried things might get a little toasty? No problem! With full control over the system cooling and lighting effects using the Corsair iCUE ecosystem, paired with four Alphacool 480mm radiators, eight Corsair LL120s, dual pump reservoir combos per system, you can be sure it will stay cool as you crank up the heat on the battlefield.

3 AESTHETICS

Combining bright and vivid custom paint that represents the Intel branding with contrasting water cooling loops, the Intel Gamer Days Enyo Dual system is a spectacle like no other.

Want to tell the world you have the ultimate system without having to even say anything? Make a statement visually with this bespoke build that is certain to be the centerpiece of any dream setup.

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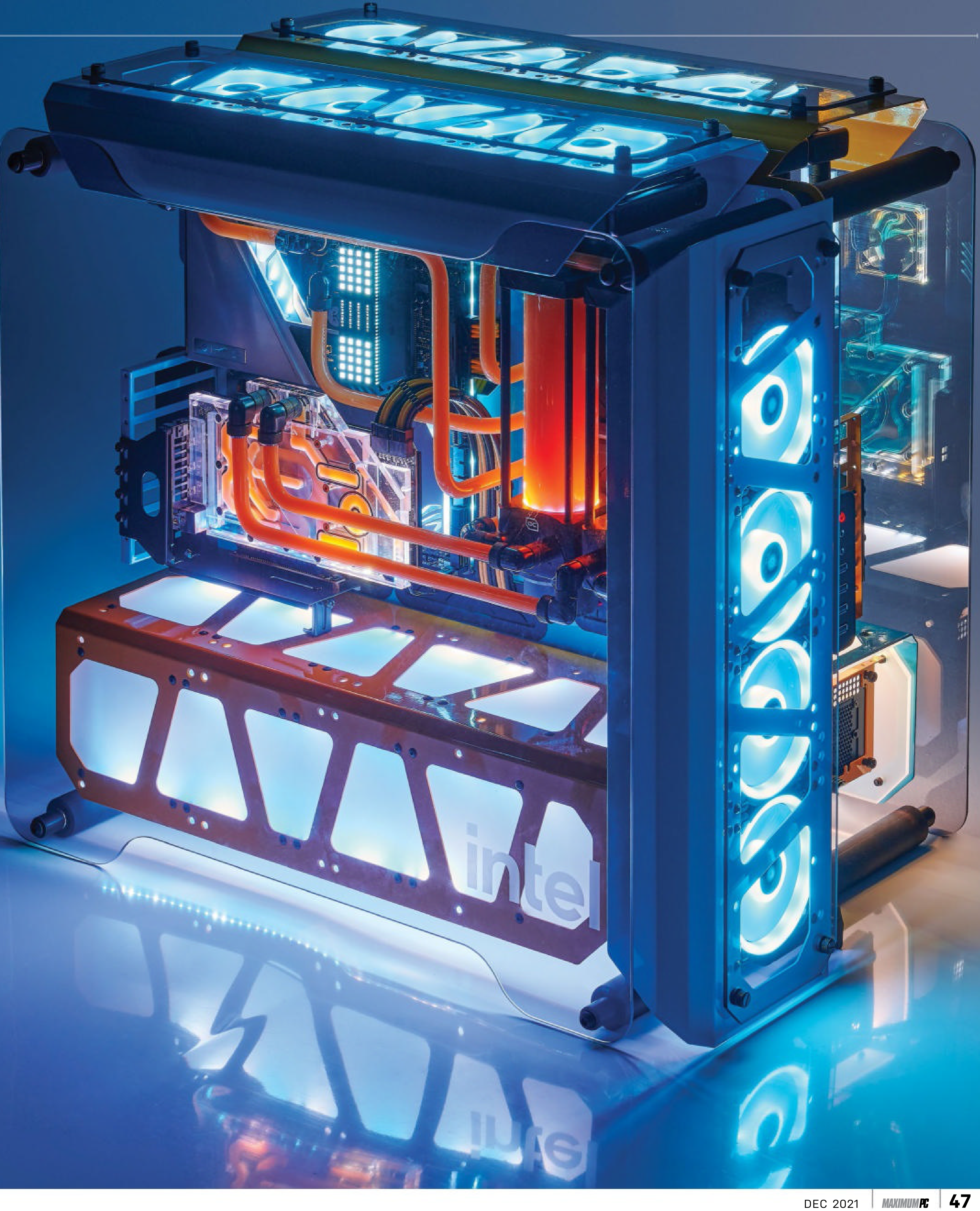
*This sweepstake is not being run by Future or *Maximum PC*. Intel's terms and conditions apply, you can find those here: https://www.prizeo.com/campaigns/INTEL/INTEL-GAMER-DAYS-2021/OFFICIAL-RULES


intel

THE GAMES OF 2022

What's coming to PC in 2022? *Christian Guyton* breaks down all the games we can expect to see next year.

2021 HAS BEEN A MIXED YEAR for PC gaming, with standout hits such as *Deathloop* and *Resident Evil Village* almost drowned out by a sea of mediocre titles and endless delays and cancellations. Happily, 2022 looks like being a more exciting year, with a whole host of original games and sequels on the way. Many of these upcoming releases have been in the works for a long time, including *Starfield* (the concept work for which began way back in 1997) and *Elden Ring*, the latter of which has been on many a gamer's mind for years. Yes, we know George RR Martin is involved. Hopefully, the game comes out before *The Winds of Winter*.

Some of these games don't have official release dates yet, so we've limited our list to titles that are confirmed releases in 2022—delays notwithstanding! We've included a broad range of games from different genres and publishers but, of course, you can expect the usual suspects to crop up in 2022; we'd be shocked if there wasn't a *Call of Duty* or *FIFA* release. So, here are the 22 games we're most excited to play on PC in 2022.

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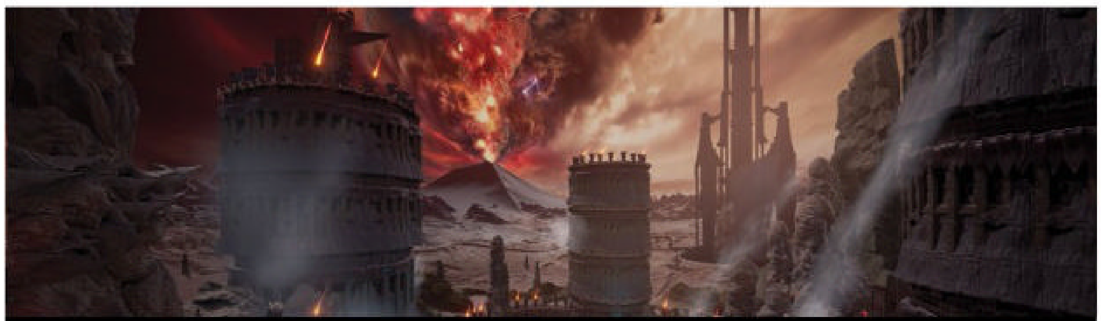
Marvel's Midnight Suns **Release Date: March 2022**

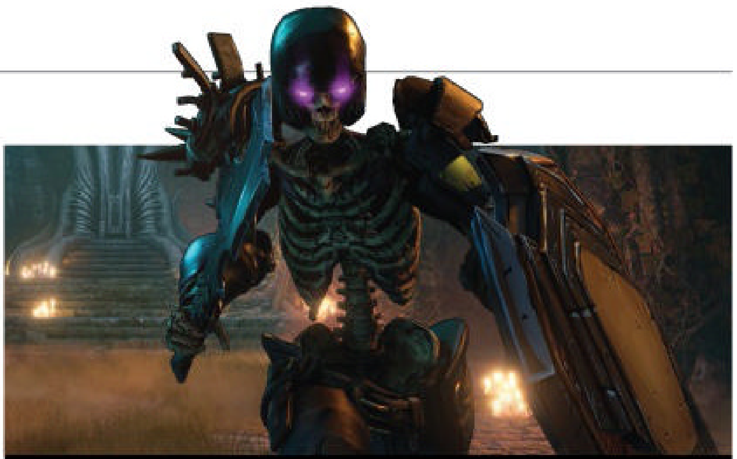
Confusingly based on the Marvel comic series *Rise of the Midnight Sons* (yup, Sons rather than Suns), this is potentially the most interesting superhero game coming to PC next year. An XCOM-esque strategy title from genre veterans Firaxis, *Midnight Suns* features a customizable protagonist named 'The Hunter', who will join up with a selection of Marvel heroes including Wolverine, Iron Man, and Ghost Rider. Intriguingly, the turn-based gameplay is supported by card-based mechanics, with your deck influencing what abilities you can use on each mission. In classic XCOM fashion, you'll manage a home base called the Abbey between expeditions.
» **Developer:** Firaxis » **Publisher:** 2K Games



The Lord of the Rings Gollum

Release Date: 2022

Why *LOTR*'s resident gremlin gets his own game is beyond us, but it's coming in 2022 nonetheless. A stealth platformer from Daedalic Entertainment, *Gollum* follows the titular hero's life prior to the events of the original trilogy, as he hunts down his 'precious'—that's the One Ring. Gollum is no fighter, so being sneaky and smart is the order of the day, whether you're luring an orc into a trap or creeping past a group of war beasts. One interesting mechanic is Gollum's split personality; Smeagol, the hobbit he once was, still exists within him, and your gameplay decisions will influence which side comes out on top. » **Developer:** Daedalic Entertainment » **Publisher:** Daedalic Ent., Nacon



Tiny Tina's Wonderlands

Release Date: 25th March 2022

A Dungeons & Dragons-themed spinoff from the *Borderlands* series, this is more of the same co-op shooting fare, set in a vibrant fantasy world, where grenades are replaced with spells and players can wield melee weapons for the first time. *Wonderlands* is the first game in the series to let players create a character rather than choosing pre-existing protagonists. » **Developer:** Gearbox Software » **Publisher:** 2K Games

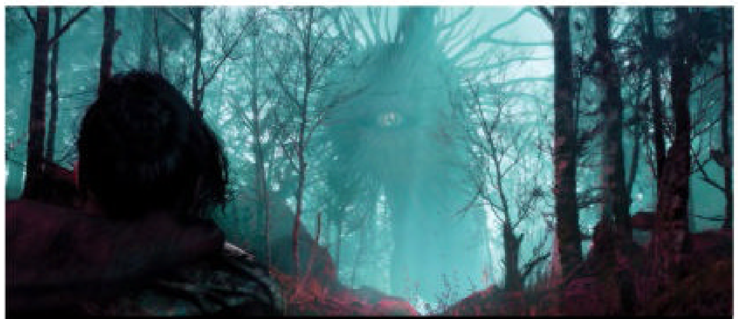
Ark 2

Release Date: 2022

Despite the sizeable active player base of *Ark: Survival Evolved*, developer Studio Wildcard is pushing ahead with a second game, promising bigger and better things for the dinosaur-packed sandbox game. Somewhat unexpectedly, the sequel will feature Vin Diesel in a starring role, as the actor is apparently a huge *Ark* fan. Players can expect a more robust story this time around, as well as plenty of the same dino-taming antics offered by the original.

» **Developer:** Studio Wildcard

» **Publisher:** Studio Wildcard



Forspoken

Release Date: Spring 2022

This action-adventure title from Luminous Productions tells the story of Frey, a girl transported to the fantasy land of Athia via a good old-fashioned magic portal. Frey has a few magical powers, from blasts of fire and ice to incredible speed, to navigate Athia's open world. Frey can sprint and leap fluidly through ruined towns and dark forests as she journeys to save Athia from an evil dictator. » **Developer:** Luminous Productions » **Publisher:** Square Enix

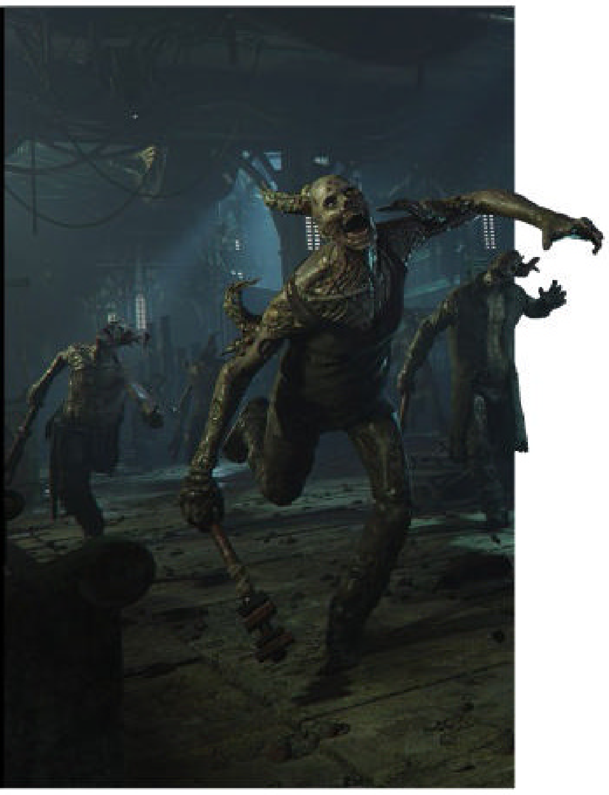
Warhammer 40,000: Darktide

Release Date: Spring 2022

From the developers of the excellent *Warhammer: Vermintide* series, *Darktide* takes us to the depths of the hive city of Tertium, where four players battle for survival against hordes of ghastly monsters. It's a side-step into sci-fi for *Vermintide*, offering the same co-op experience enhanced by a new setting and what Fatshark calls 'deep and balanced gunplay'. *Warhammer 40,000*'s universe is peak grimdark science-fiction, a violent dystopian setting that provides the perfect backdrop for *Darktide*'s brutal combat.

» **Developer:** Fatshark

» **Publisher:** Fatshark



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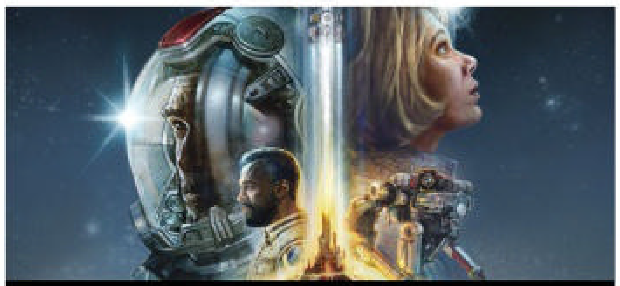
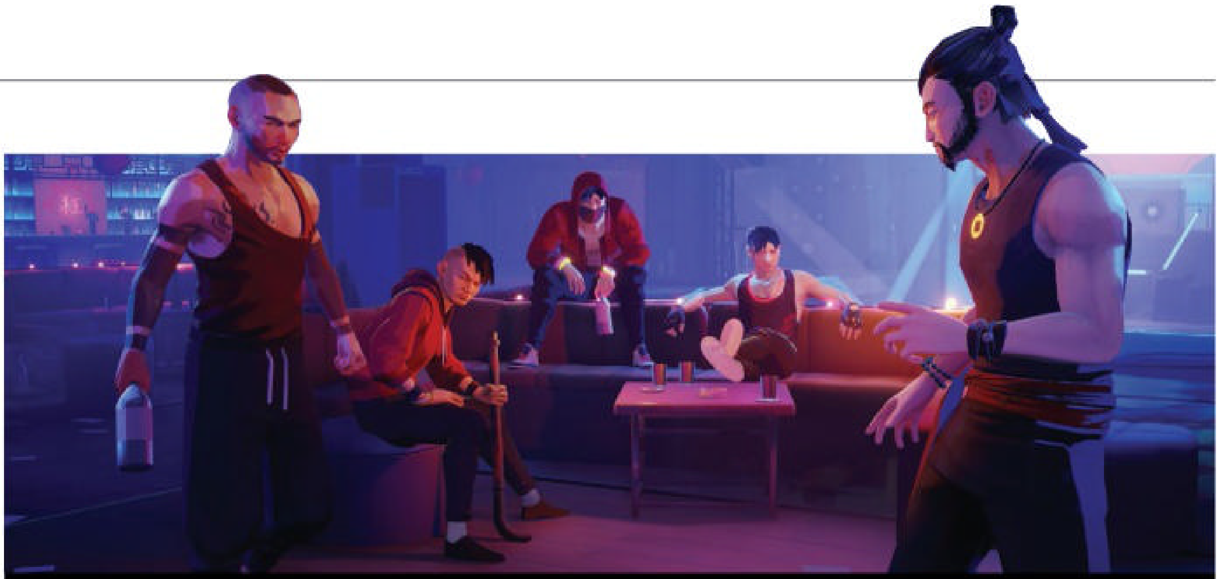


Starfield

Release Date: 11th November 2022

Starfield is the first new IP from Bethesda in a quarter of a century. Set 300 years in the future, it casts you as a spacefaring explorer working for a group named Constellation. You are tasked with braving the depths of space through a combination of role-playing, on-foot action sequences, and combat missions.
» Developer: Bethesda Game Studios
» Publisher: Bethesda Softworks



Sifu

Release Date: 22nd February 2022

One of the most interesting original IPs on this list, *Sifu* tells the tale of a young kung fu master on a journey of revenge and redemption. Hand-to-hand combat is the core of this game: martial arts techniques and brutal takedowns flow together in a symphony of violence, backed by a simple but clean cel-shaded art style. The setting is a visually distinctive neon urban backdrop, and surrounding environments offer plenty of room for improvisation; pick up a brick and throw it to briefly incapacitate an enemy, or grab a broken bottle to use as a makeshift weapon. **» Developer:** Sloclap **» Publisher:** Sloclap

Slime Rancher 2

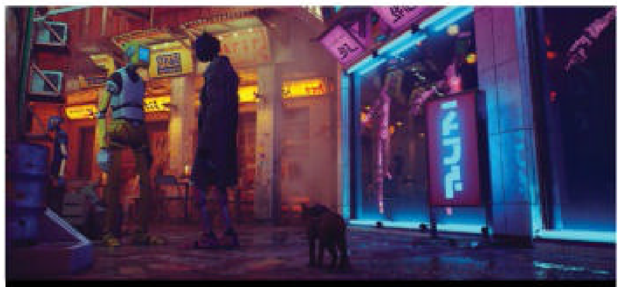
Release Date: 2022

Slime Rancher was a sleeper hit from 2017, its brightly-colored gameworld concealing plenty of ranch-management depth as you collected and bred a variety of charmingly jiggly blobs. This sequel sees protagonist Beatrix journeying to a distant island to discover new breeds of slime. Expect more of what made the first game great: exploring, puzzling, and hoovering up hordes of slimes with Beatrix's vacuum gun before depositing them in corrals back on the farm.
» Developer: Monomi Park
» Publisher: Monomi Park

The Outlast Trials

Release Date: TBA

The third installment in the Outlast series, this prequel takes us back to the Cold War to struggle for survival in a harrowing medical experiment. The survival-horror gameplay on show here is familiar, but new to the series is co-operative multiplayer, where up to four players can work together to escape from a number of sadistic trials. It has all the horror tropes you could wish for: creepy puppets, abandoned laboratories, and haunted fairgrounds. As the game's description on Steam says, "It's better to sh*t your pants with friends". **» Developer:** Red Barrels
» Publisher: Red Barrels



Stray

Release Date: Early 2022

You play as a cat in a cyberpunk city populated by robots—no, we can't make it sound any cooler than it already is. *Stray* looks gorgeous, with a setting inspired by the iconic Kowloon Walled City. You'll be navigating platforming levels and solving puzzles as our fearless feline hero. The city's robot denizens with their TV-screen heads make for a distinctive aesthetic.
» Developer: BlueTwelve Studio
» Publisher: Annapurna Interactive

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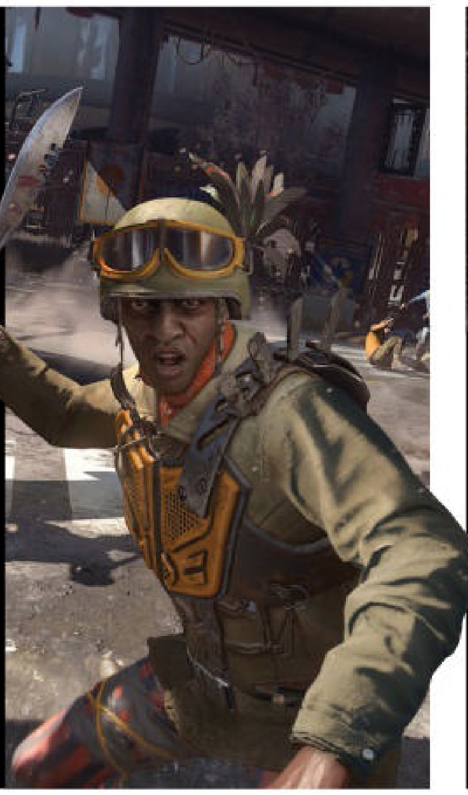
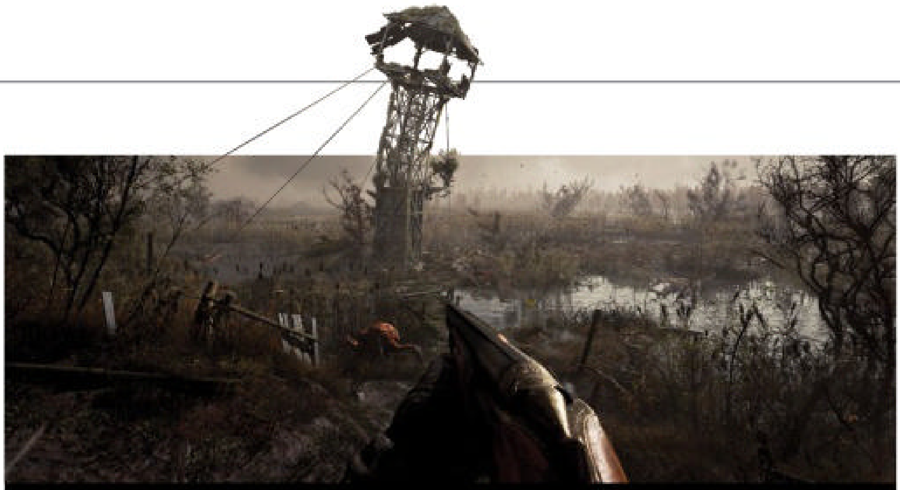
Dying Light 2: Stay Human

Release Date: 4th February 2022

The original *Dying Light* was a flawed but fun first-person zombie slayer, and a 20-year gap brings new zombie types and a fresh protagonist. The parkour elements of the first game return, with over 3,000 unique animations. A grappling hook and paraglider open up opportunities for escaping and ambushing the undead, and a crafting system allows you to build weapons. *Stay Human* also features a four-player co-op mode. » **Developer:** Techland » **Publisher:** Techland

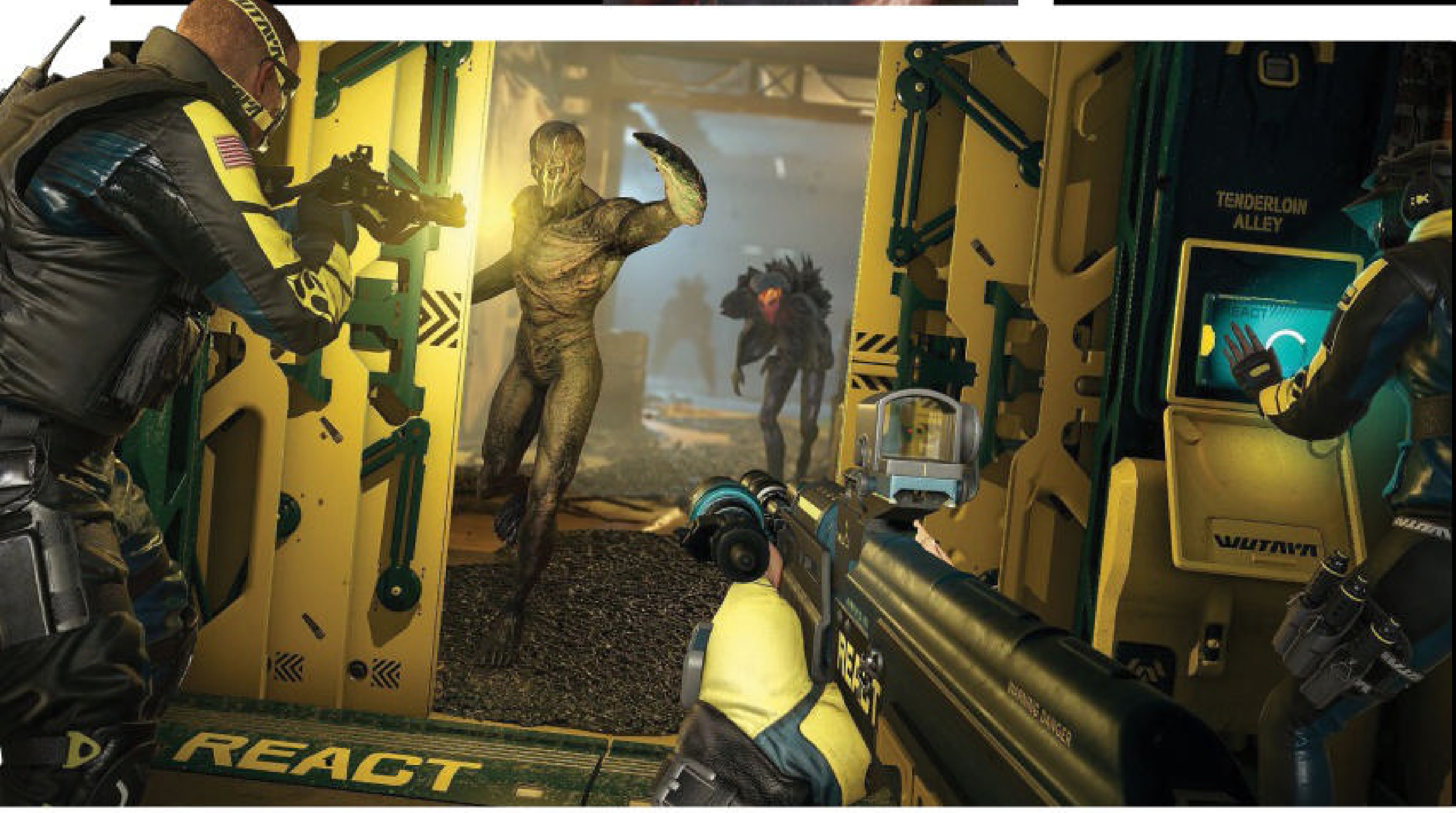




S.T.A.L.K.E.R. 2: Heart of Chernobyl

Release Date: 28th April 2022

This hotly-anticipated installment of the *S.T.A.L.K.E.R.* series is set in the Chernobyl Exclusion Zone in Ukraine, where radiation has created terrifying mutants and physics-breaking anomalies. A first-person shooter with horror and survival game elements, the aim is to venture into the depths of the Zone in search of valuable artifacts with paranormal powers. » **Developer:** GSC Game World » **Publisher:** GSC Game World



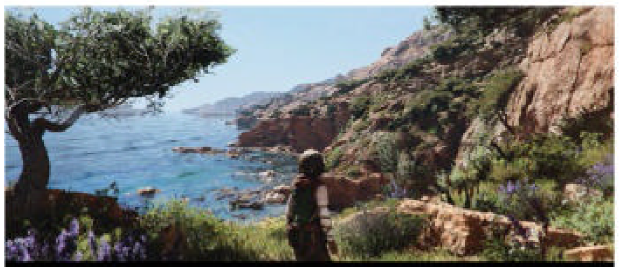
Tom Clancy's Rainbow Six Extraction

Release Date: January 2022

A spin-off of multiplayer shooter *Rainbow Six Siege*, *Extraction* takes its predecessor's spec-ops heroes and throws them into a sci-fi survival scenario, where players fight bloodthirsty hordes of parasitic aliens. Elements of *Siege* remain, such as using drones to recon areas and destroying walls to create new pathways through levels.

» **Developer:** Ubisoft

» **Publisher:** Ubisoft



A Plague Tale: Requiem

Release Date: 2022

A sequel to the award-winning *A Plague Tale: Innocence*, this action-adventure title sees protagonists Amicia and Hugo on the run as the Black Death ravages 14th-century France. The sequel delves into supernatural themes, with a 'terrifying curse' following the sibling. Expect to see a lot of plague-ridden rats.

» **Developer:** Asobo Studio

» **Publisher:** Focus Home Interactive

Redfall

Release Date: 2022

Following the success of *Deathloop*, Arkane Studios is looking to new horizons with *Redfall*, a stylized open-world shooter with co-op multiplayer that sees players take on the role of one of four vampire-hunters. With a slick animated trailer introducing our wisecracking heroes, Arkane knows how to handle character design. The four characters each have unique abilities, and collecting and upgrading weapons will be a core part of the gameplay experience. This is a *Borderlands*-type game from the developers of *Dishonored*, which sounds pretty cool.

» **Developer:** Arkane Studios

» **Publisher:** Bethesda Softworks

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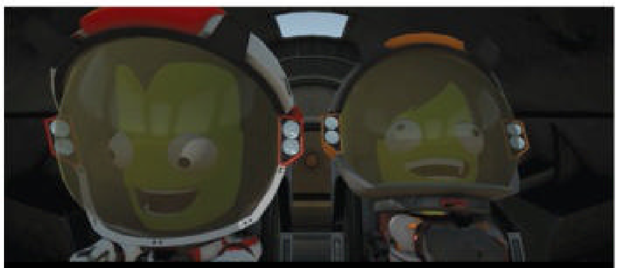
Baldur's Gate III

Release Date: 2022

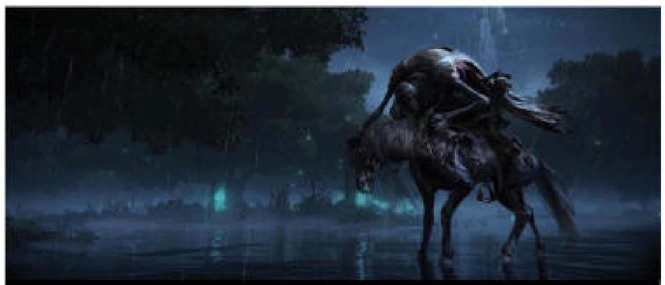
Baldur's Gate is an RPG series set in the Dungeons & Dragons universe, spawning many spin-offs and setting the bar for fantasy role-playing games. This long-awaited third entry shifts the focus from hack-and-slash to turn-based combat, but keeps the deep character customization and branching narrative elements. An early-access release is already available on PC, its launch causing technical issues on Steam due to unexpectedly strong sales. The complete game will feature a gameworld five times larger than what is currently available, with over 16 playable races and an expected 12 character classes to choose from.
» Developer: Larian Studios
» Publisher: Larian Studios



Kerbal Space Program 2

Release Date: 2022

Despite the silly nature of *Kerbal Space Program*, the developers have worked with astrophysicists to ensure it is the most 'realistic' spaceflight sim possible. New features include interstellar travel, colony-building, and multiplayer. We can't wait to crash another rocket into the moon. **» Developer:** Intercept Games
» Publisher: Private Division



Elden Ring

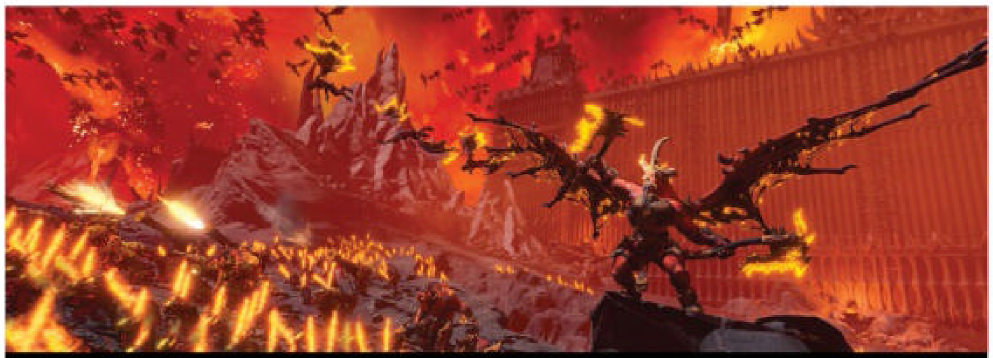
Release Date: 21st January 2022

Elden Ring has RPG elements aplenty propping up a grueling, stamina-based combat system where the slightest mistake can mean death. It introduces new elements such as horseback riding and stealth mechanics, though From Software's staple feature of summoning other players to help out in tough boss fights will make a return.
» Developer: FromSoftware, Inc
» Publisher: Bandainamco

Oxenfree II: Lost Signals

Release Date: 2022

Oxenfree II delivers more of the same creepy decision-based narrative excellence offered by the first game, with a new setting and protagonist. Environmental researcher Riley Poverly returns to her hometown of Camena to investigate a series of electromagnetic anomalies, only to become embroiled in a ghost story. The original *Oxenfree*, released in 2016, featured time-loops and malevolent spirits alongside amusing teen drama, so we can't wait to see what direction this sequel goes in. **» Developer:** Night School Studio **» Publisher:** MWM Interactive



Total War: Warhammer III

Release Date: 2022

The latest entry in the series takes the setting to the terrifying Realm of Chaos and introduces new factions and units. Gameplay-wise, we can expect the same complex real-time strategy content, overhauled with new mechanics and updated graphics. Developer Creative Assembly has stated that a chunk of content from the first two games will carry over to this threequel, so don't fret if you've already spent your hard-earned cash unlocking playable races in those games.
» Developer: Creative Assembly **» Publisher:** SEGA, Feral Interactive

Gotham Knights

Release Date: 2022

With the Arkham trilogy officially concluded, WB Games Montreal looks set to continue the trend of open-world beat-em-ups set in the DC universe. In *Gotham Knights*, players take control of Robin, Nightwing, Batgirl, or Red Hood in a lawless Gotham City. Two-player co-op is on the table, along with a wider range of combat abilities. The villains of the piece are the Court of Owls, an iconic group from Batman lore. **» Developer:** WB Games Montréal
» Publisher: Warner Bros. Interactive Entertainment

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HOW TO

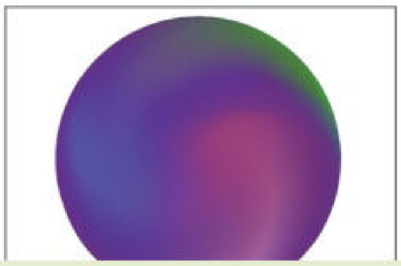
STEP-BY-STEP GUIDES TO IMPROVING YOUR PC

TIP OF THE MONTH

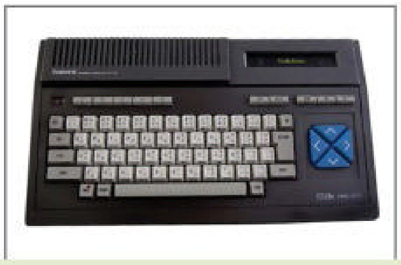
RESTART GRAPHIC DRIVERS

Sometimes your PC has a brain freeze, and the go-to fix is to restart your machine, the classic turn it off and on again. However, this shortcut may be worth trying instead. If your PC screen freezes or inputs are delayed, hit Win+Ctrl+Shift+B to restart your graphic drivers. Your screen may flicker, but everything should soon be back to normal. Open applications won't close, so try this before the old-school way next time.

MAKE – USE – CREATE



58
How to add color gradients in Adobe Illustrator



64
Travel back to 1985 with Japan's MSX2 machine

68
AMD vs Intel in a battle of the integrated GPUs

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SAM LEWIS
STAFF WRITER

SETUP IMPROVEMENTS

So in the last issue, I mentioned that I decked out my setup with Elgato streaming gear that I'd been sent for review testing. So far so good, using these peripherals has made productivity and communicating a breeze. And anything that boosts productivity gets a thumbs up from us journalist folk.

However, for the past few weeks, I have been house-sitting, meaning that I have had to work from my beloved 13-inch Macbook pro again. This laptop has been, for the most part, demoted to the 'media center' back home and spends most of its life connected to the TV. Out with the old and in with the new, that old chestnut.

Anyway, I can safely say that I am excited to get back on an ultra-wide monitor and a PC that doesn't lag on Chrome (not asking for much, am I?). To give credit where it's due, my Macbook is seven years old and is still usable. Yet, I am so glad to get back to normal in my new setup. If you are productivity-focused and don't yet have a ultrawide, it's well worth getting one. Having everything open on one screen instead of constantly flicking between applications sounds like a small issue, but is a great help. Let's just say, I am glad to be back, and unfortunately for my Mac, it will be back under the TV unit for now.

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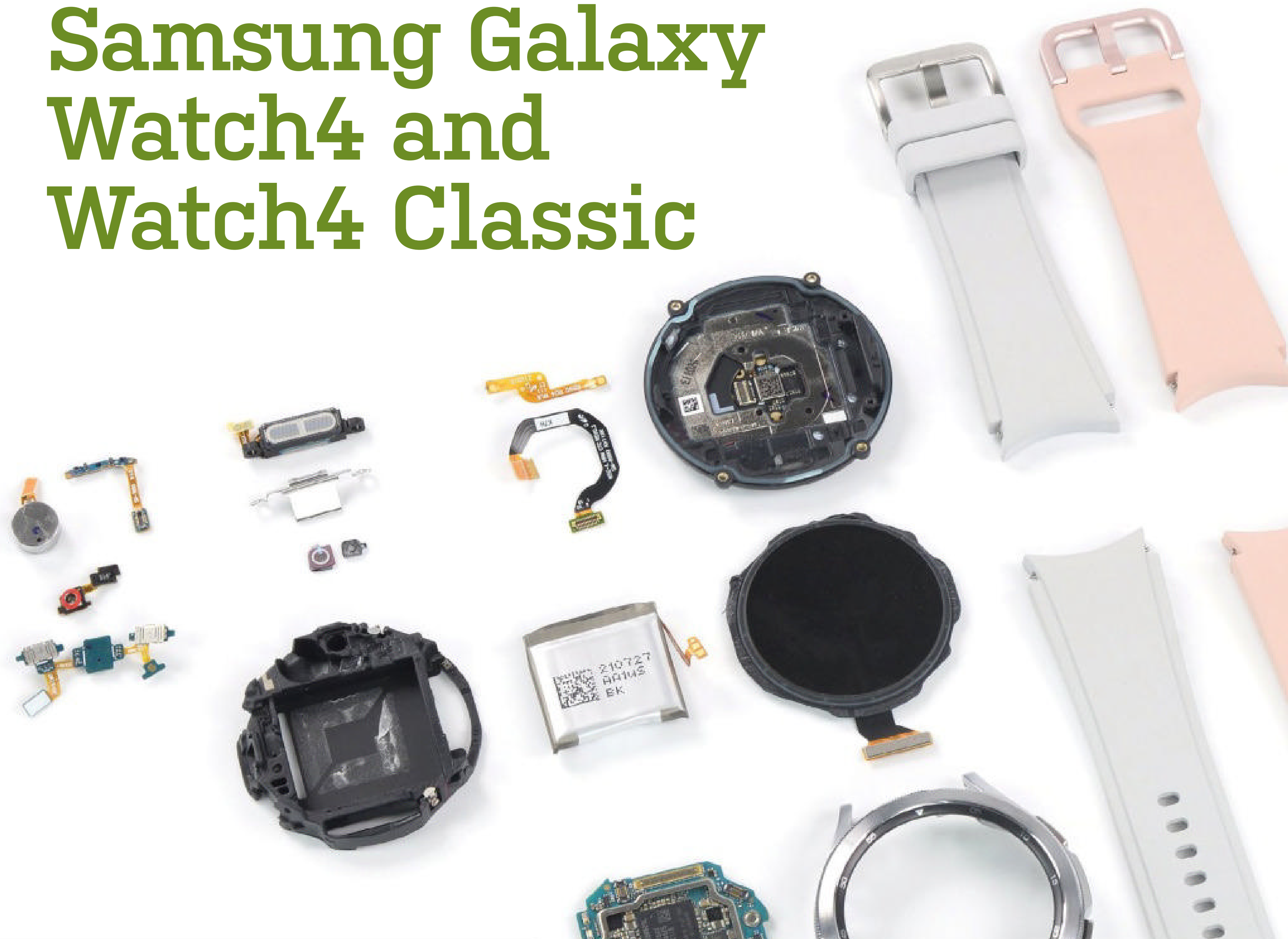
IFIXIT presents:

AUTOPSY

THIS MONTH WE DISSECT...

Samsung Galaxy Watch4 and Watch4 Classic



Both the standard and Classic Watch4 models ditch the previous round buttons, seen on the Watch3, for sleek rectangular buttons.

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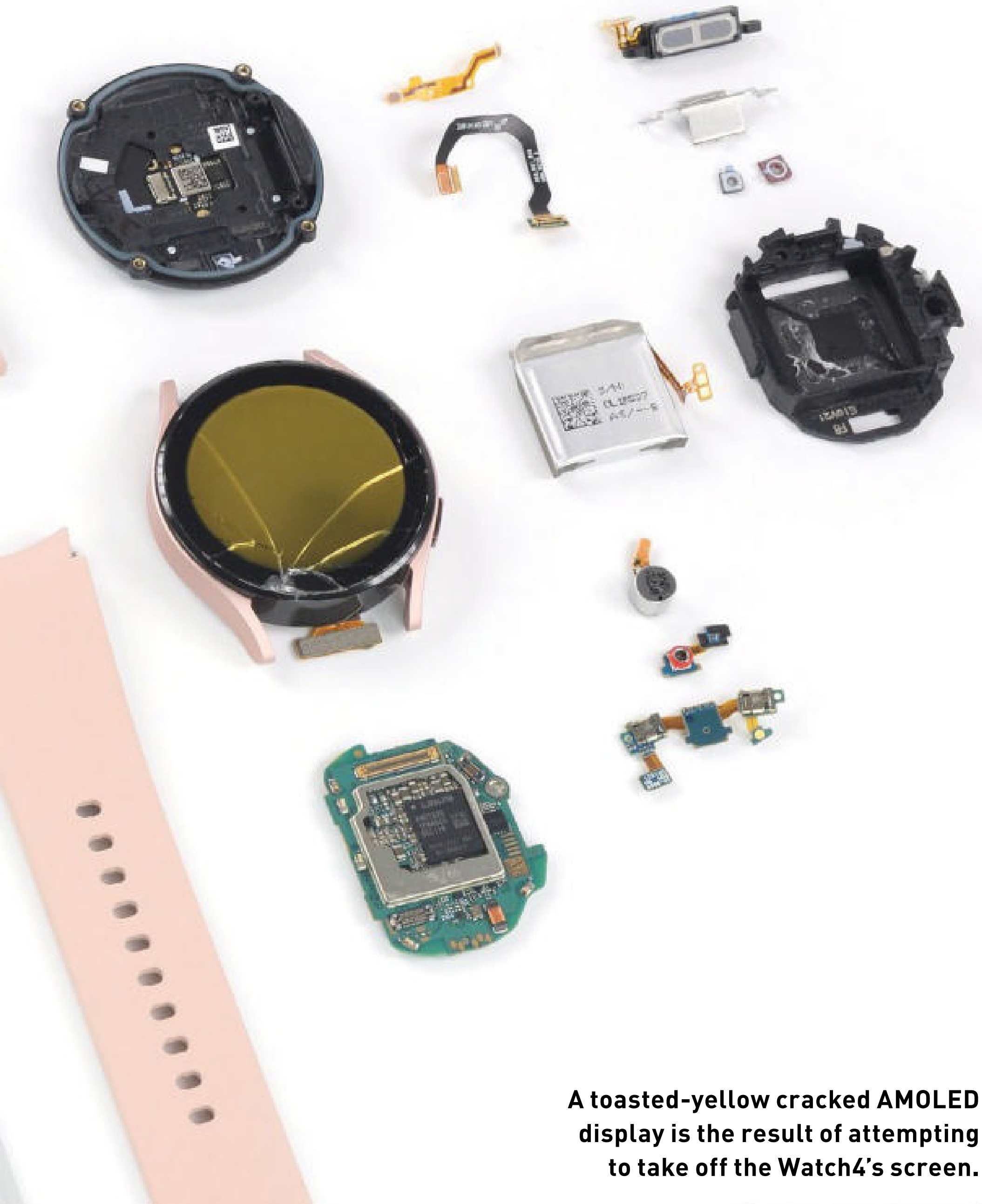
Placed next to each other, the Classic (left) maintains the rotating bezel from the Watch3, whereas the Watch4 (right) is the sleeker model of the two.



A toasted-yellow cracked AMOLED display is the result of attempting to take off the Watch4's screen.

BACKGROUND

Samsung recently unveiled two updates to its smartwatch line in the Galaxy Watch4 and Galaxy Watch4 Classic. Though externally similar to last year's Watch3, there's a good chance of internal differences, and we're here to sniff them out. Time for a teardown!

MAJOR TECH SPECS

- Exynos W920 1.18GHz with dual ARM Cortex-A55 cores, Cortex-M55 display processor, Mali-G68 GPU, and integrated LTE
- Circular Super AMOLED always-on display—1.19-inch or 1.36-inch sizes (both models) 330 PPI
- 1.5GB RAM and 16GB internal memory
- 361 mAh battery, Watch4 Classic (46 mm). 247 mAh battery, Watch4 (40 mm)
- Sensors, including accelerometer, barometer, gyro, geomagnetic, light, optical heart rate, ECG, bioelectrical impedance sensor, and a Hall sensor on the Classic
- IP68 rating with water resistance to a depth of 50m (5 ATM)

KEY FINDINGS

- Though the Galaxy Watch4 and the Galaxy Watch4 Classic have almost identical specs, they each rock their own look. The Watch4 Classic is bulkier but has some classy stainless steel or titanium frame options. Both models open up through the back: a specialty driver easily takes care of the four tri-point screws and a quick pry from an opening tool gets us inside.
- What we find is: a Samsung package combining the Exynos W920 dual-core 1.18GHz processor with 1.5GB of their in-house LPDDR4, Samsung Shannon 915 intermediate frequency IC, Broadcom BCM43013 ultra low power dual-band 802.11n Wi-Fi and Bluetooth 5.0 combo IC, and likely a Qualcomm Atheros QPA5580 power amplifier. The back of the Watch4 (not the Classic) shows us a couple more of those same chips: S915 intermediate frequency IC and a Broadcom BCM43013 ultra low power dual-band 802.11n Wi-Fi and Bluetooth 5.0 combo IC.
- The fuel tanks are hidden under the motherboards, nestled within plastic midframes, and can be removed with the help of a sturdy spudger. The Watch4 Classic accommodates a 1.40Wh (361mAh @ 3.88 V) battery, while the Watch4 houses a 0.95Wh (247mAh @ 3.88 V) battery.
- We shake the last components out of the midframe and find a familiar vibration motor next to the barometric sensor. The most interesting part is the button flex cable. It not only carries a microphone but is also equipped with a contact plate opposite its connector. This allows the watch to close an electrical circuit through your body for bioelectric impedance analysis.
- The Watch4 Classic prioritizes simple display removal. With a little heating, we separate the circular AMOLED screen from the frame with a push. Unfortunately, the standard Watch4 isn't so friendly. We grab our heating and prying tools and promptly crack the screen. Whoops! At least if you're prying the screen off, it's probably already broken. Tick, tock, it's score o'clock. Our journey through two Galaxies comes to an end.
- Repairability Score: 7 out of 10 (10 is easiest to repair). Opening it is straightforward and requires some prying, but no heat. The batteries are easily accessible and use only mild adhesive. With a little heat, the display of the Watch4 Classic can be removed without any additional tools. Only two types of screws are used, although the back cover screws are uncommon tri-points. Both watches are modular, with only the rear sensors being buried inaccessibly in the back cover. The Watch4's display sits in the frame and seems impossible to remove without damaging it.

Gradients, patterns and all things shiny.

YOU'LL NEED THIS

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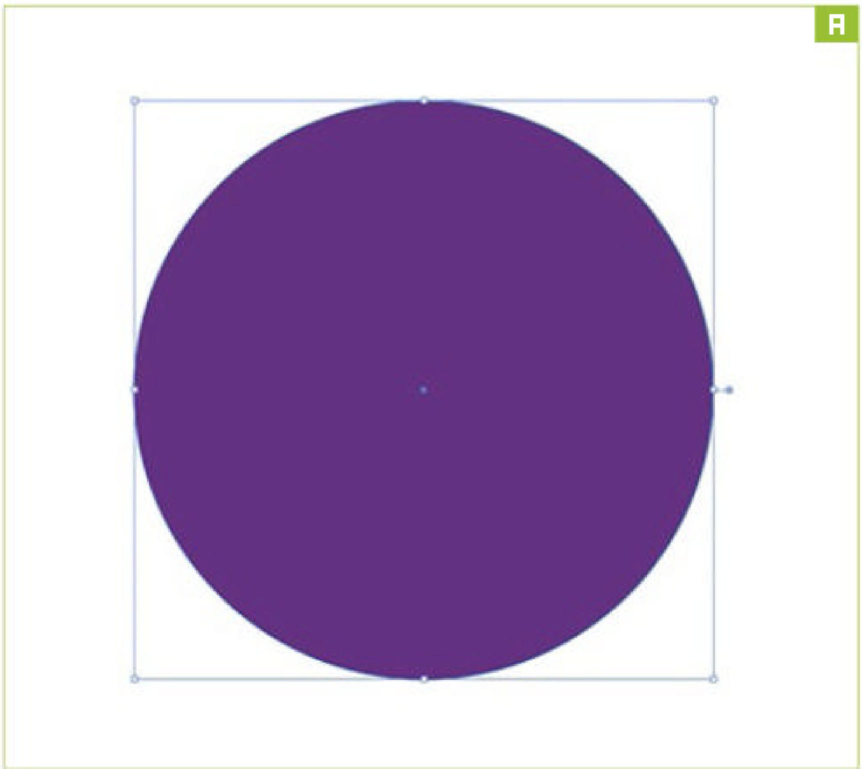
IN DESIGN, YOU SOMETIMES NEED your work to have an element of the wow factor. Yes, we are talking about the glitz and glamor of creative work. A great way to really spice up your designs is to introduce gradients and shiny textures into your themes. For example, Apple's advertising relies heavily on this style of art, with the company often pairing this with clean photography to create a high-contrasting and striking image. And we can safely say that Apple is doing a pretty decent job in respect of its advertising campaigns.

There are many ways you can implement this technique in your work and it's up to you how you add these elements and get creative with these patterns and texture styles. They can be used in text, backgrounds, and wallpapers to create shapes, outlines, branding, editorial work, and much more. In this tutorial, we will learn how to create these gradients, make some cool-looking shapes out of them and look at how to implement them elsewhere. –SAM LEWIS



1 DRAW A CIRCLE

In simple terms, gradients are created using a range of hues and tones that blend smoothly together. Sure, you can create a jagged mosaic-style gradient effect, but we are focusing on the more traditional smooth gradient. We are going to be using the cleverly named gradient mesh tool to help us out with this tutorial. First, though, you need to have a few set colors in mind that you would like to incorporate together and that complement each other. For example, these could be accent colors in an existing design to which you would like to give a new lease of life.

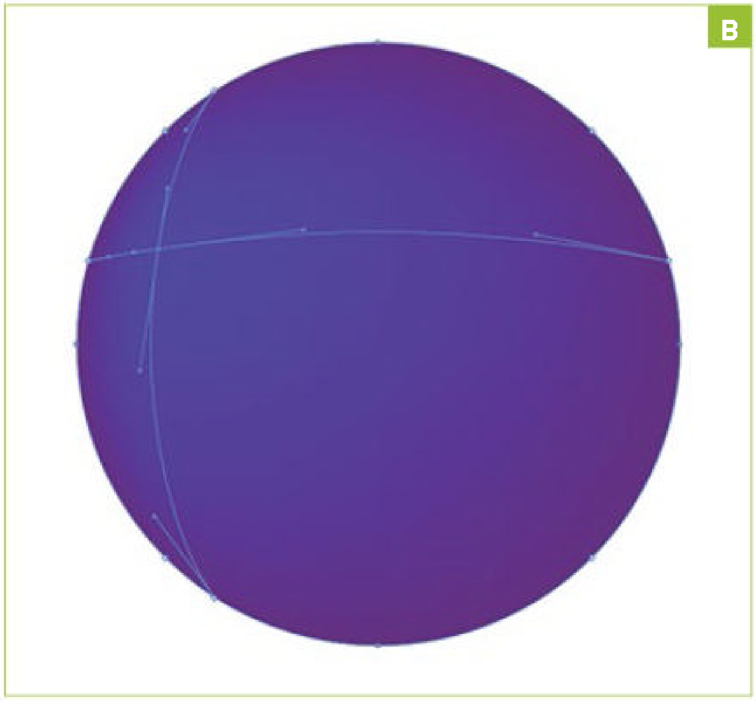
›› To kick things off, we are going to create some fun gradient orbs. Create a document of any size you prefer, then choose a color mode that suits you. We know we often repeat this, but it's important—CMYK for print and RGB for digital. Head over to the left tool panel and find the ellipse tool. If you can't see this straight away, it will be hidden under the rectangle tool menu. This icon will have a drop-down menu, so click and hold on this tool and you'll see all the shape options pop up. Find the circle and hey presto you've got it [**Image A**]. Now draw a quick circle and fill it with a bold color or one that fits your color scheme. Make sure to clear the stroke on the shape too.

2 USE THE MESH TOOL

After creating your circle, head over to the left tool panel again and find the mesh tool. Yes, surprisingly, we aren't using the gradient tool yet. Click a point in this circle and change the color to something that fits your theme. Or it could either complement or contrast the original color. The next thing to do is use the mesh tool again and create some more points of color within this shape. Just remember, you can use this within any shape, a circle is just a handy way of showing off the pattern. Choose another similar color to add to the shape. You can play around with the handles using the direct selection tool to change the swirl of the mesh tool color too [**Image B**]. The tools in Illustrator allow for plenty of customization, they all mix and match together so you can always expect to create something unique when using this application.

3 CREATE A SMOOTH BLEND

Keep adding more colors in empty spaces around the circle until you are happy with your color spread. The mesh tool will automatically create a smooth blend between the hues and the effect should



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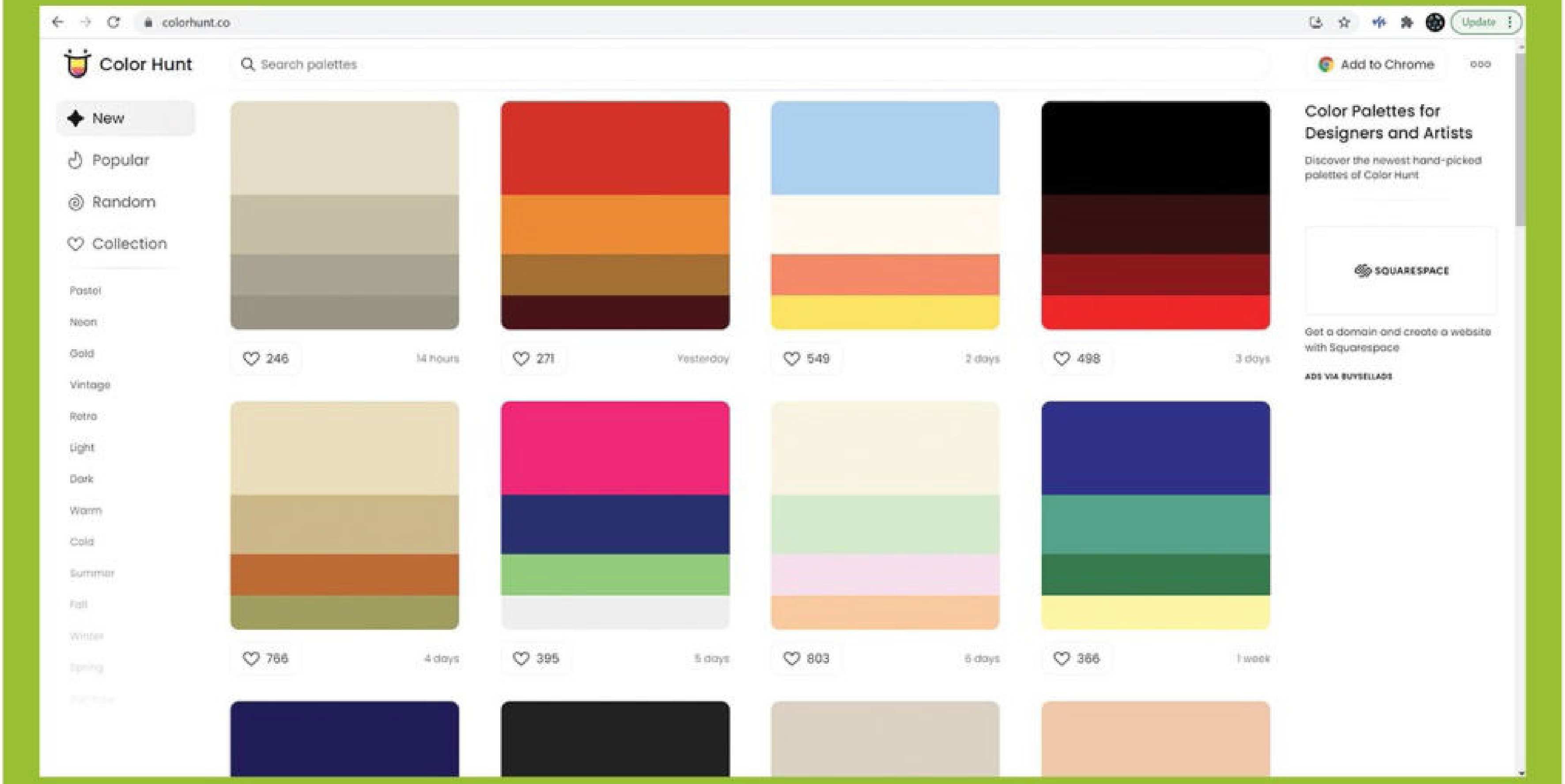
COLOR HUNT



Color Palettes for Designers and Artists

Discover the newest hand-picked palettes of Color Hunt

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A major part of the designing process is selecting colors that you can incorporate throughout your design. This is known as part of the design language. You may see these colors appear as part of the logo, typography, accent colors, and any additional branding. There are certain colors that you associate with a brand and that's the ideal scenario. Select a few colors to keep cemented in your work, it will gradually become synonymous with those colors.

Ideally, you don't want more than four main base colors when creating work. Any more than this, and your work could become a little overwhelming and it could lose some of its design language. Sure, this isn't a one-size-fits-all rule, but take this into consideration when creating a style. As we said at the start of this tutorial, Apple's design language usually follows some striking yet minimal product photography with a flick of color to create a high contrasting look. Using the tips we have seen today, you will be able to recreate some of your own creations in this style.

A great website to check out is colorhunt (https://colorhunt.co). Swatches are important to have on the side of your work in your design software. It's vital to note down the color values, whether that is the CMYK, RGB, or HEX values. The last thing you want is to choose the slightly wrong color as it will stick out like a sore thumb. Colorhunt is basically a mood board-style website that helps you pick out a bunch of swatches. Down the left-hand side of the site, there are categories for the type of design look and feel you are going for. There are lots of different palette options available, you can create your own and there are also lots of collections to take a look at.

When you find a color palette you like, you can click into the swatch and find the exact RGB or HEX codes right there for you. You can even download the image to add to the workspace of your design so you can refer back to it. It's a community-based system, so if you are happy with what you see, give it a like rating. There is plenty to enjoy, so go take a look and get some inspiration for your next project.

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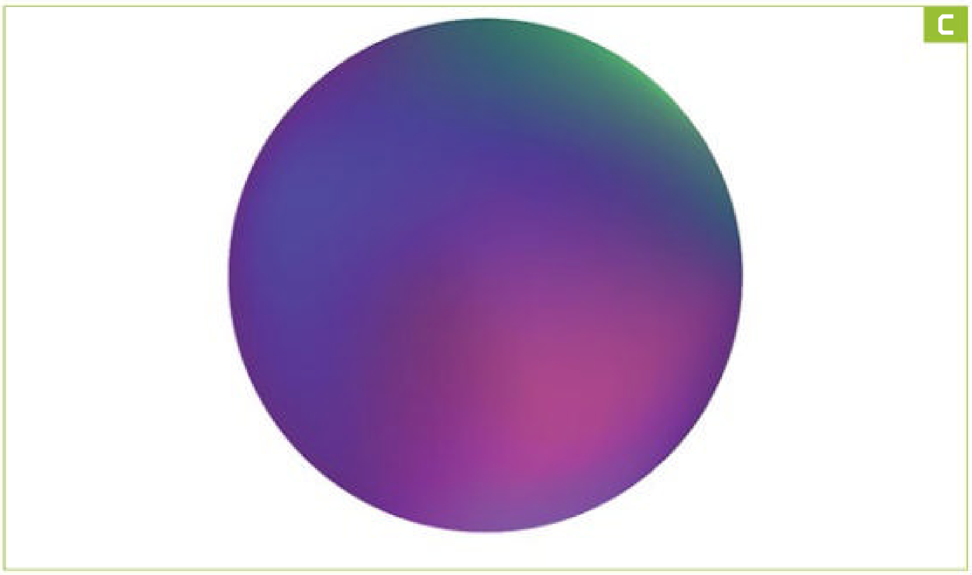

start to look pretty smooth already. You can add color at any point in the circle, not just where you have created points using the mesh tool. A good tip to create a more three-dimensional shape is to add highlights around the edge of the circle by using slightly lighter hues. Use this on one point to create an effect as if there was a light source just out of shot [**Image C**].

4 GIVE US A TWIRL

How about we add a bit more wow factor? Again, we aren't going to be using the gradient tool just yet. Instead, we will need help from the twirl tool. This is hidden under the width tool drop-down menu in the left tool panel and, somewhat annoyingly, it doesn't have a shortcut by default. Petty irritations aside, double-click on the tools icon to open the pop-up setting window

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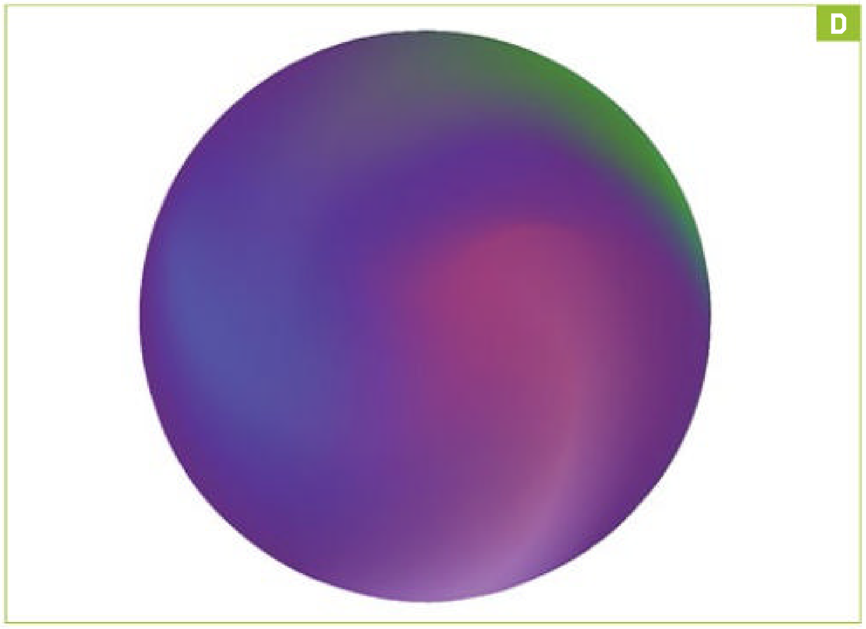


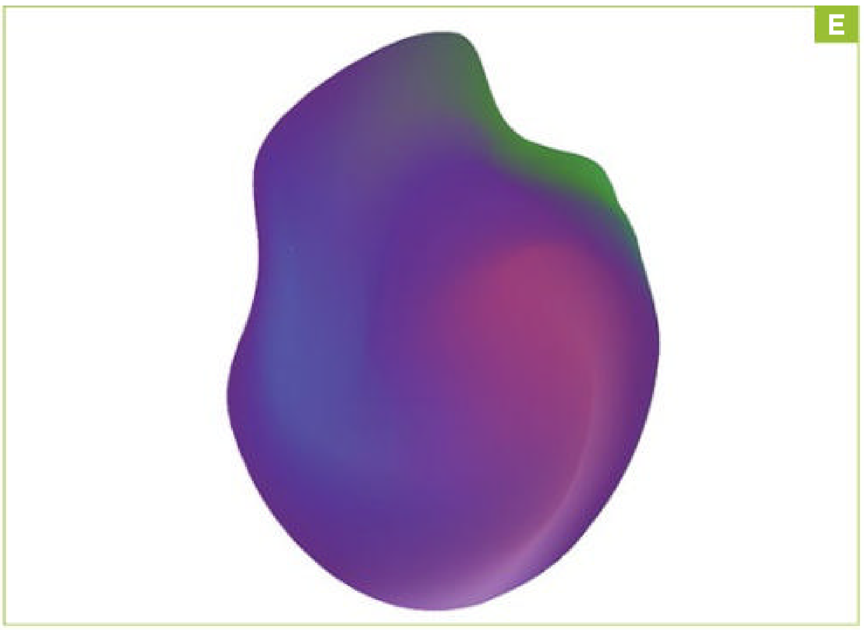
for it. Now you need to adjust the width and height of the brush dimensions to a similar size to your circle. Then lower the intensity to 10 percent.

›› This next bit can be quite fiddly, but thankfully there is a fantastic creation called the undo shortcut, it's probably the part of the keyboard we use the most. Design work certainly requires a lot of trial and error and patience too, so don't fret if you find yourself using it a lot. Anyway, less of the philosophy, let's get back to work. Click in the circle and carefully mix the colors around using small adjustments at a time [**Image D**]. Bigger adjustments can cause some distorting and glitching, which isn't exactly what we are after here. Once you have swirled things around a little, it should look a little like this.

5

WARPED PERSPECTIVES

Hopefully, things are beginning to take shape now, so it's perhaps time to get bent out of shape and mess around with the structure of this circle. We're going to try and create an orb-like image and so the warp tool will be our best friend here for this job. Once you are happy with how your color scheme is looking, then you can crack on with messing around with the shape. Double click the warp tool to open up the pop-up settings and change the intensity up again. Drag gently from the edges to adjust the shape. Keep switching back and forth between this tool and the twirl tool until you have achieved your desired look. You can then use the direct selection tool to alter the points and make whatever shape you like. The beauty of all these tools is that you can create an authentic gradient using these little tips and tricks. [**Image E**].



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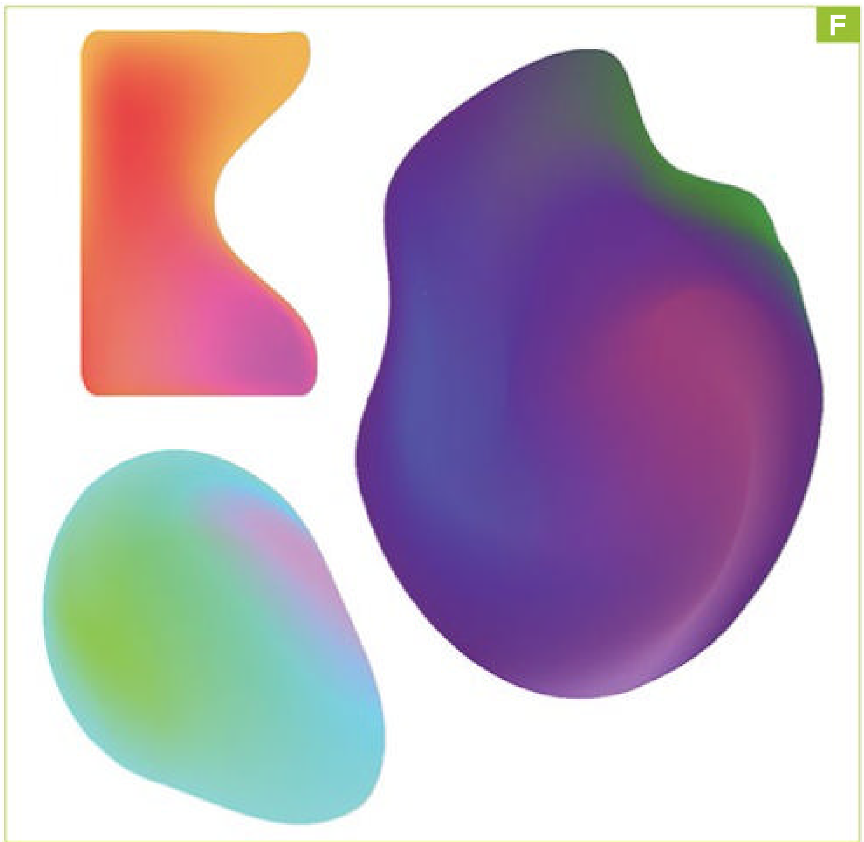
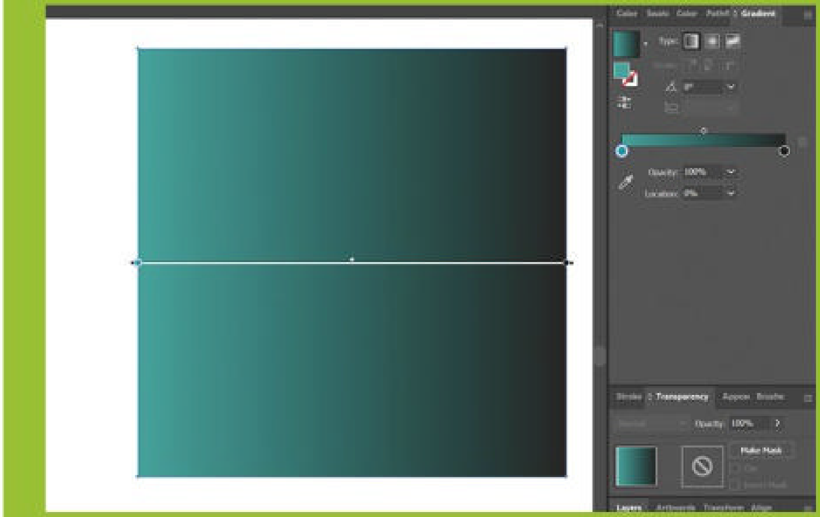


›› As seen above, we tried this on a variety of shapes to create a nice bit of abstract art. This is a great way to create a wallpaper or a background behind some branding. Use this to your advantage and hopefully you can add that little bit of spice to your designs [**Image F**].

LINEAR OR RADIAL?



If you fancy a more simplistic gradient effect, then you will need the standard gradient tool. This is located in the left-hand side tool panel or by pressing the 'G' key. First, you will need to draw your shape, then open the tool and click inside the desired shape. It should automatically create an even linear gradient from one side to the other. Or if you click on the radial gradient option in the pop-out window, it will create an even round gradient effect.

You can adjust the length and get a more precise gradient by drawing a line in the shape using the tool. There are also options to change the angle, opacity, and colors. You can choose the point at which you want the colors to appear in the gradient using the slider bar, which is the best way to create a smooth custom gradient. Practice using this to create more formal gradients in your work, you can get some interesting and rewarding results using this tool.

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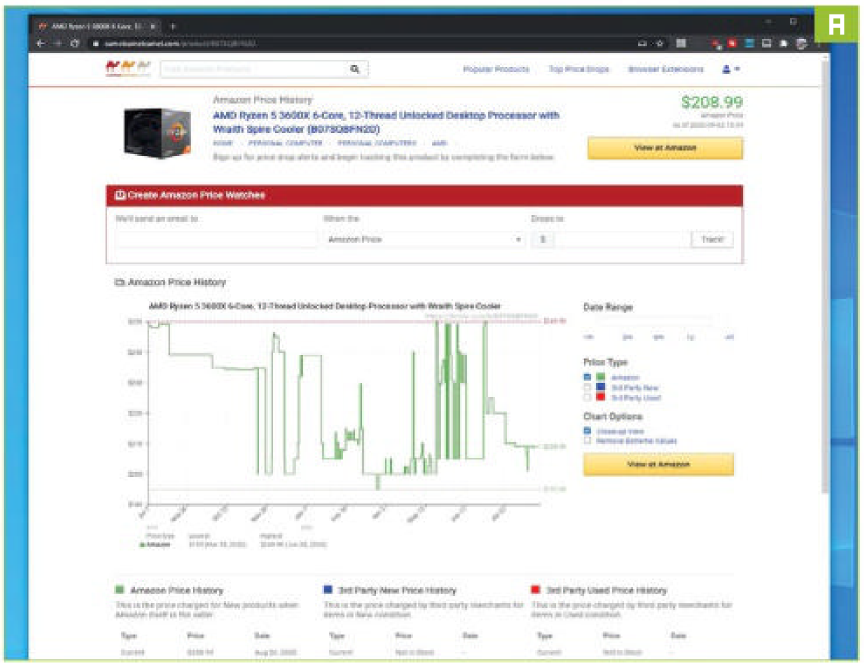
Some deal-listing sites, and your favorite etailers.

CAN NOVEMBER really be rolling around again? Yep, and that can only mean one thing—Black Friday is just around the corner. It's the best day of the year to get great deals on PC kit, but how do you get the best deals and how, exactly, does it all work?

The easy answer is to log on to the websites of *Maximum PC*'s sister titles, including www.techradar.com, www.tomshardware.com and www.pcgamer.com and let them do the heavy lifting for you. All the best deals are neatly categorized and simple to select. But that leaves the question of how those websites themselves go about selecting the best deals.

You're in luck, for your erstwhile correspondent has been a member of the crack deal team on several occasions. Here's your behind-the-scenes peek at how it all works, and what that means for you and getting the best deals. –**JEREMY LAIRD**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Popular Products
Top Price Drops
Browser Extensions
Amazon Price History
AMD Ryzen 5 3600X 6-Core, 12-Thread Unlocked Desktop Processor with Wraith Spire Cooler (B07SQBFN2D)
$208.99
View at Amazon
Create Amazon Price Watches
Amazon Price
Track!
Amazon Price History
AMD Ryzen 5 3600X 6-Core, 12-Thread Unlocked Desktop Processor with Wraith Spire Cooler
Date Range
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1 MANUAL WORK AND DEAL-MAKING

The first and perhaps most surprising fact about Black Friday deals is that it's all done manually. In an age where AI is all the rage, you might think that choosing deals would lend itself nicely to an algorithm. As in many other disciplines, the scope of AI has been exaggerated, and it's humans that add the value. The fact that deal listings aren't done by AI says a lot about the maturity of that so-called technology. But that's a story for another day.

›› The next surprising fact is that it's relatively laborious and depends significantly on existing knowledge, and not just using the right search tools. Many leading etailers, including Amazon, the behemoth of online outlets, don't make it particularly easy to find deals in specific categories. Yes, filters can be applied, but they don't always work reliably or as expected. So a heap of manual trawling goes into the mix.

›› What you may not be surprised to learn about is the kickback for websites recommending deals, otherwise known as affiliate commission. Many websites display a message saying, "When you purchase through links on our site, we may earn an affiliate commission". In short, the website recommending the deal gets a small cut if you link through and buy. If that sounds fishy, it isn't. Serious players in deal listings have arrangements with all the major etailers, so the interests of the websites listing deals are perfectly aligned with yours. The better the deal they point you at, the more likely you are to buy and earn them a little cut.

2 PRICING AND EXPERIENCE

But what of pricing, surely the most critical factor in any deal worth the name? Pretty much all participating etailers play it fairly fast and loose with their definition of a deal. In other words, the advertised saving isn't always what it seems. It may not be indexed against the price just before Black Friday, but compared to another earlier and higher price that was only in place for a relatively brief time and isn't terribly representative of a product's typical cost. Overcoming that involves a combination of experience and a few online tools.

›› For Amazon, there's a handy tool for tracking any deal against its historical price. Simply load up https://camelcamelcamel.com [**Image A**] and drop the product's Amazon URL into the search field and you'll see whether the deal price is actually any good. There are more generic tools, such as https://pcpartpicker.com and Google Shopping, which can also be useful. The problem, however, can be timeliness. Some of the best deals are gone in a flash. That's where experience counts. The ability to quickly recognize a good deal without the need to cross-reference historical pricing saves critical time.

3 BUYER'S GUIDE

As for what you, the deal-shopper, should do, we'd recommend combining the best of *Maximum PC*'s sister websites with a little manual searching of your own. By using the likes of techradar.com, tomshardware.com and pcgamer.com, you're benefitting from a dedicated team of deal hunters who can cover far more of the web than you could on your own.

›› The catch is that some of the best deals appear and disappear so fast that solely relying on deals fed to you by third parties could mean missing out. So it's a good idea to have the relevant sections of several of the top etailers saved as browser favorites for easy access. Also consider signing up for various early-access memberships, such as Amazon Prime. ⏻

DEAL-LISTING SITES:
techradar.com
tomshardware.com
pcgamer.com

TOP BLACK FRIDAY ETAILERS:
amazon.com
newegg.com
bestbuy.com
walmart.com
bhphotovideo.com
ebay.com

Machine of the Month: MSX2 (1985)

YOU'LL NEED THIS

AN INTERNET CONNECTION

A DECENT BROWSER

Get openMSX at openmsx.org or WebMSX at https://webmsx.org/

THIS MONTH, WE HEAD back to Japan to revisit the MSX standard with its 1985 sequel, the MSX2. While the original MSX machines were fairly middle-of-the-road 8-bit microcomputers, the second-generation version gained a big jump in performance. The MSX2 introduced key improvements to the base RAM (64K to 512K), video memory (64K to 128K, with higher resolution, more color, and support for vertical scrolling), and sound chip specifications. For fans of the Sega Master System and Nintendo Famicom (NES), MSX2 computers provide a genuine alternative that will make any Japanese game geek salivate. –**JOHN KNIGHT**

1 A POWERFUL UPDATE

The MSX was a standard for 8-bit microcomputers developed by Microsoft Japan in cooperation with the ASCII Corporation. If every MSX computer had a set of standardized components, software written for one should, in theory, work on any other.

» In May 1985, the MSX2 standard was announced, bringing a substantial performance, but remaining backward compatible with the MSX.

» While the new MSX2 standard was designed by the ASCII Corporation, Microsoft continued their software support for the system with MSX-DOS 2.0, which came on a separate cartridge and closely resembles MS-DOS 3.3.

» Curiously, the MSX2 uses the same 3.58MHz Zilog Z80A CPU found in the original MSX—its substantial power gains come from its other components.

» Where the old MSX usually had between 32-64KB of RAM (8KB minimum), the MSX2 starts at 64KB, with other models ranging from 128KB to 512KB.

» Video processing was enhanced with its new Yamaha V9938 VDP. This 21MHz powerhouse was usually coupled with 128 KB of VRAM, allowing 16 colors from a 512 color palette @ 512 x 212, or 256 colors @ 256 x 212. Sprite handling is especially improved with a maximum of 32 sprites on-screen using 16 colors.

» Sound received a minor upgrade with the Yamaha YM2149 sound chip, a clone of the General Instruments chip found in the MSX with small improvements. However, in 1986 Konami, in collaboration with Toshiba, released the SCC "Sound Creative Chip"—a much more advanced chipset. Although it was originally used only in game cartridges, clever workarounds spawned a new scene of demos, music disks, and sound utilities.

2 GAMING

On the whole, MSX2 gaming is an impressive experience, with graphics, sound, and gameplay that often exceeds the kind of gaming found on the Master System or NES.

» However, MSX2 machines have a strange Achilles' heel: they don't have hardware-assisted four-way scrolling, which was essential for the kind of 2D platformers and RPGs that eventually ruled in the 1980s.

» This often resulted in a strange gaming experience, where graphics were often sharper and more detailed than anything from Sega or Nintendo, but many games used simple flick-screen designs, as found on an Amstrad or ZX Spectrum.

» Nevertheless, the MSX2 provides some brilliant gaming, especially for Konami fans. Of particular note are the first two *Metal Gear* games, which are the real first two installments, not the games released by Nintendo.

» Some other famous Konami titles include *Vampire Killer* (1987), a variant on *Castlevania*; an enhanced version of *King's Valley II* (1988); and *Space Manbow* (1989), a sophisticated scrolling shooter with impressive story animations.

» Beyond Konami's range, other noteworthy titles include *Shin Maou Golvellius* (1988), *Psycho World* (1988), *Aleste* (1988), and *Aleste 2* (1989).

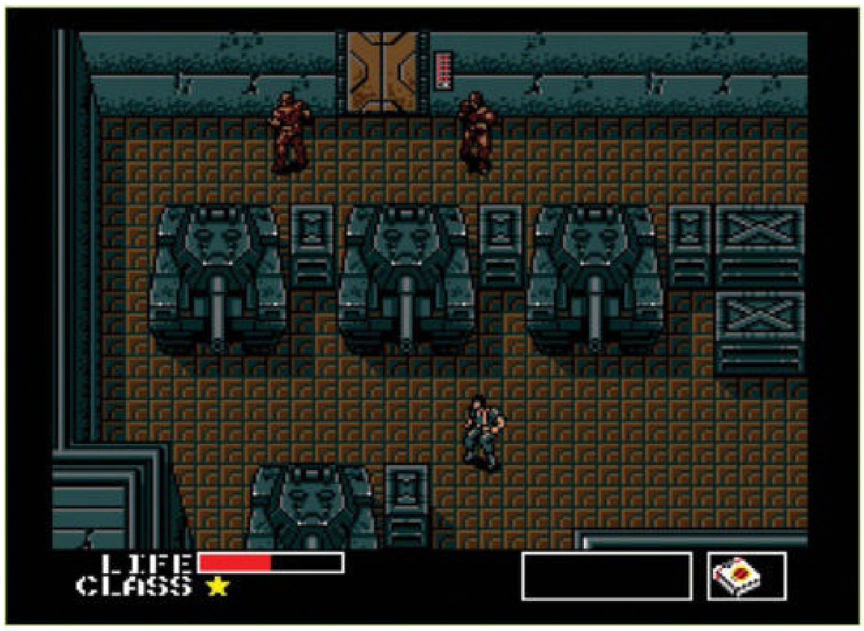
3 LEGACY

Although Japanese sales went well, the concept did not become the worldwide standard Microsoft had planned. Microsoft pulled out of the MSX project in 1986, leaving the ASCII Corporation to continue alone.

» With all the different manufacturers worldwide, researching MSX sales numbers produces wildly varying figures, from estimates of 5 million sales worldwide to 9 million in Japan alone. Write in if you know the answer.

» In 1988, ASCII updated the standard with the MSX2+, which upgraded the video processing, allowing 19,268 colors instead of 512. An FM-PAC cartridge was also included, with better audio and more sound channels. The MSX2+ was only available in Japan and Korea.

» The series ended with the TurboR in 1990: a 16-bit machine that wasn't fully backward-compatible with the previous generation, and only produced by Panasonic.



© KONAMI, 1987

» *Metal Gear* (1987) on the MSX2 marked the true beginning of the series. The famous Nintendo version was made by a different team and had no input from the original creator Hideo Kojima.

›› With better video processing, MSX2 gaming was much improved.

4 EMULATION

When we covered the original MSX, we chose openMSX as our preferred emulator, but we'd now recommend WebMSX. Although we wouldn't normally choose browser-based emulators, WebMSX is solid and doesn't require system ROMs.

›› If you would still prefer an offline application, see our March 2021 issue, which has instructions for openMSX. Both WebMSX and openMSX have MSX2 support, but WebMSX is easier to use.

›› To get started, just visit webmsx.org and WebMSX will load a BASIC prompt, ready to run anything you like. (If a file is compressed in ZIP format, you can open it without extracting it).

5 LOADING CARTRIDGES

Cartridges are the easiest format to use. To load a cartridge file, either click the "load files" link or drag and drop a file onto the browser window. Or load the cartridge manually by clicking one of the icons at the bottom of the WebMSX window, and choosing 'Load ROM Image' from the pop-up menu.

›› The emulator will reset and load straight from the cartridge. If you're finished with your cartridge and want to perform other tasks, use the cartridge menu to remove the image.

6 LOADING DISKS

It's worth browsing the disk menu. Other than "Load Disk Images", you can "Add Boot Disk" or "Import Files to Disk".

›› Unlike cartridges, simply loading a disk won't do anything, but don't panic. Most disks have an MS-DOS style autoexec.bat (or .bas) file. Reset the virtual MSX by clicking the Power icon, followed by Reset, and most disks will boot automatically.

SPECIFICATIONS

MSX2 (1985)

CPU:	Zilog Z80A @ 3.58MHz
VRAM:	64 to 128KB
RAM:	64 to 512KB (more RAM is theoretically possible)
ROM:	48KB BASIC
Graphics:	Yamaha V9938, 512x212 with 16 colors from 512, or 256x212 with 256 colors, 32 sprites with 16 colors
Sound:	Yamaha YM2149 PSG
Storage:	Cartridge, cassette, 5.25 and 3.5-inch floppy add-ons
OS:	Microsoft MSX BASIC 2.0 and MSX-DOS 2.0
Released:	May 1985
Worldwide sales:	N/A

WHERE DO I FIND SOFTWARE?

There are a fair few ROM sites out there but, unfortunately, we can't recommend them for legal reasons. However, the two best sites you can use are msx.org and msxgamesworld.com, which have extensive archives (including demos and public domain software, which is something we *can* legally recommend).

New games are still being made for all MSX systems. One good source is www.retroworks.es. We liked *Sword of Ianna* (2017), with Prince of Persia style gameplay in a barbarian RPG setting, and *Knight Lore Remake* is a visually impressive remake of an isometric puzzle classic.

7 LOADING CASSETTES

Before loading cassettes, some programs display an error, asking you to remove the disk drive.

›› To do so, click the Settings icon at the bottom-right of the screen. Near the top of the menu is the option "Floppy Drives". Click this twice, and the icon will turn from red to gray. This disables your floppy drives—clicking the icon until it's red again will re-enable them.

›› To load a tape, follow the same instructions as with disks or cartridges. Like disks, nothing will happen initially—you need to manually load the program. Click the tape icon at the bottom of the screen, and from the pop-up menu click "Run Program".

8 TWEAKING WEBMSX

Sooner or later, you will need to tweak WebMSX's settings for an application to work properly.

›› Some games such as *Metal Gear* require a Japanese system, but the default system is an American MSX2+. To use a Japanese system, click the Settings icon and choose "Select Machine". This will provide a list of different machines from around the world, including systems from every generation of MSX.

›› Some applications require the SCC sound cartridge. This is enabled simply by clicking Settings, then selecting "Konami SCC+" from the pop-up menu.

PTS 12850
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›› Capcom was another famous MSX publisher. *Higemaru Makaijima: Nanatsu no Shima Daiboken* (1987) is a hidden gem for anyone into swashbuckling pirate adventures.

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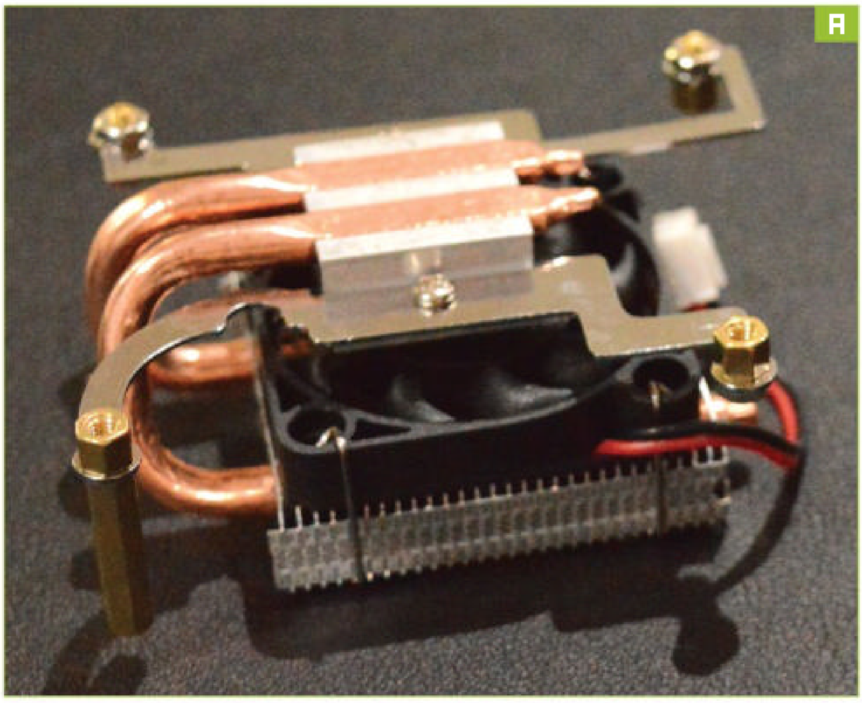
Fit a Raspberry Pi 4 inside a custom case

YOU'LL NEED THIS

RASPBERRY PI 4 (4GB OR 8GB)
DeskPi Pro case
Phillips screwdriver

WITH UP TO 8GB OF RAM, USB 3.0, a quad-core CPU, and dual-band WiFi5, the Raspberry Pi 4 is the first iteration that can deliver a consistent, reliable desktop experience. But to fulfill that potential, you need a desktop case with space for additional storage, full access to the USB ports, and a reliable cooling solution. Among the various solutions available is the $55 DeskPi Pro from SeeedStudio (www.seeedstudio.com). It has everything you need to turn your Pi into a desktop system and delivers a great experience, but setup can be tricky.

You can't search through a list of Raspberry Pi accessories online without tripping over a bunch of cases. These range from the official white and red case to LEGO-compatible boxes, transparent cases, layers of plastic stacked one on top of the other, and various DIY solutions. With so many options for keeping your Pi free from dust, splashes, and other potential interruptions, it might seem strange to consider a solution such as the Argon ONE range or the DeskPi Pro. But consider the benefits: an all-in-one power supply, integrated storage; a PC-like experience; a Pi that won't get pushed around by the weight of the HDMI or Ethernet cables (or both). Plus modern luxuries such as a front-mounted microSD slot, two USB ports, and a power switch. The GPIO is also rerouted, away from the side of the Raspberry Pi to the back of the DeskPi Pro. The power of the Pi 4 (especially the 8GB model) and the robustness of Raspberry Pi OS and other compatible OSes underline the fact that this is a platform that has hit maturity. It needs a desktop case. **–CHRISTIAN CAWLEY**



1

CONNECTING COMPONENTS

Assembling the DeskPi Pro with your Pi 4 can be time-consuming. If you're used to the ease of traditional Raspberry Pi cases, you may be in for a rude awakening. Mounting the Pi in the DeskPi Pro is more akin to installing a motherboard in a traditional desktop case. Like many such cases, the DeskPi Pro features peripherals and add-ons to enable compatibility with the Raspberry Pi. Key among these is the microSD adaptor, which reroutes the microSD slot to the front of the DeskPi Pro. This small PCB easily slots into the microSD slot, with the ribbon cable connector facing up. The cooling fan assembly's mounting posts are also used to secure the microSD slot adapter in place.

2

COOLING FAN ASSEMBLY

The most complex aspect of assembling the DeskPi Pro is the cooling fan and heatsink assembly [**Image A**]. Arguably the most important stage of setting up the Pi with a DeskPi Pro case, it's vital to complete this efficiently. A wrong step here could leave you without a Raspberry Pi 4. Getting this right means first assembling the heatsink correctly. If you have experience in building full-sized PCs, you'll appreciate the requirement to build the fan and heatsink before attaching it to the CPU.

» In the case of the DeskPi Pro cooling system, a thermal pad is included for the CPU, although you might prefer to use thermal paste. Another aspect of constructing desktop PCs is reflected in this stage of the DeskPi Pro. The springy legs of the assembled heatsink must be accurately positioned for effective cooling. But what does this mean? Essentially, the heatsink should be constructed in a slightly offset manner, with more "leg" on the right-hand side of the heatsink (with the Pi's USB ports facing away from you). Completing the trio of similarities with a desktop build is the requirement to apply some pressure to correctly attach the heatsink to the Pi 4. This can be a stressful moment for your beloved Pi, and one that's best attempted with preparation. Inserting and securing the mounting poles before attaching the heatsink—and having the securing nuts close to hand—can make all the difference between success and failure at this stage.

3

RESTORING THE GPIO

Similarly, the DeskPi Pro has a GPIO adaptor. This sits comfortably on the GPIO pins, with a ribbon cable to connect to the new, rear-facing GPIO. This, in turn, is mounted above the new HDMI, UBC-C, and TRRS ports. These are part of a larger PCB that slots into place using the micro-HDMI and TRRS ports. Once the Pi is connected to the DeskPi Pro PCB, ensure both ribbon cables are correctly inserted and locked in place. Similarly, the power cable for the cooling fan should be

C

connected—the port for this sits close to the microSD adapter ribbon cable. The DeskPi Pro PCB comes ready-assembled. However, there's a key connection to be made. A heatsink mounting post (next to the TRRS port) doubles as the sole securing point for the Pi 4 (although this might differ on models without the GPIO adapter, where a second pole is present).

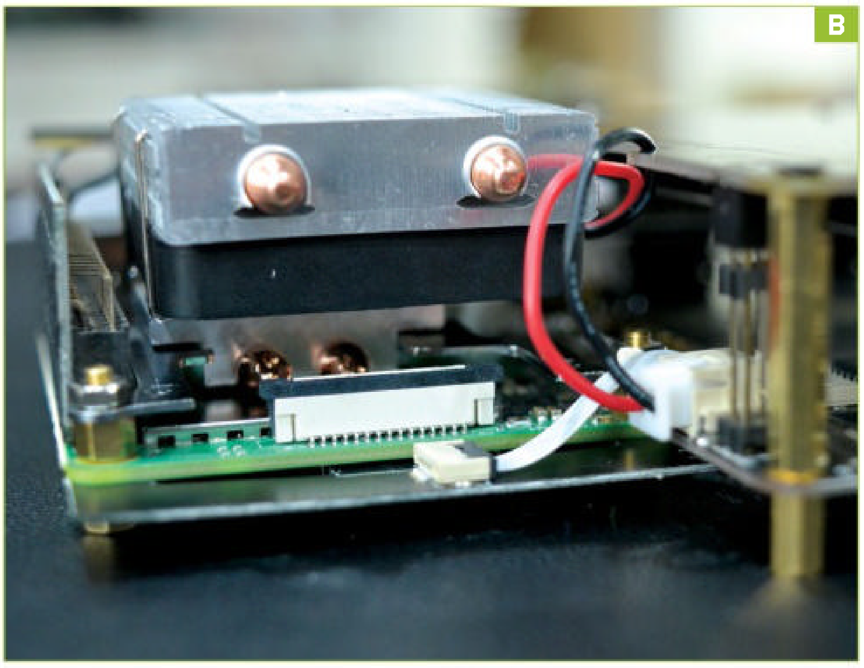
4

STORAGE OPTIONS

Unlike the Argon ONE, which is available in different M.2 and SATA models, the DeskPi Pro case gives you both options for additional storage in one. The SATA option enables you to use a standard drive [**Image B**], whether SSD or mechanical hard disk drive. Meanwhile, the M.2 option gives you the choice to connect super-fast SSD storage.

» However, you are limited to B key-only connectors. M.2 storage features three connection options: B key, (left notch, with the connectors facing away from you); M key (right notch), and a combined B+M key. A flipped B key M.2 device won't connect to an M key connector. As such, if you plan to use M.2, you'll need to ensure you're using the correct key for the M.2 slot. For the best compatibility, choose a B+M key M.2 storage device; if you want speed, use B key M.2 storage. Note that the M.2 adaptor plate will accept devices up to 80mm long.

» While the DeskPi Pro case enables you to use either SATA or M.2, you can't use both at once. So here, you face a simple choice of M.2 or SATA SSD or HDD. The M.2 stick is mounted on an adapter plate that slots into the SATA drive port. If you prefer an SSD or HDD, then set the M.2 mounting plate aside and insert your chosen device. Your drive is secured using four screws that attach it to the SATA interface plate. This employs the rarely used screw holes on the back of the drive rather than the ones on the side.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VENTING YOUR PI

With the interior of the DeskPi Pro correctly assembled, there's another challenge to face: sliding the barebones into the chassis. This might initially appear to be an utterly obvious procedure. However, and certainly with our device, it's anything but. The fact is, the DeskPi Pro will slip into position in any of four ways, but only one will align the fan with the vents. While the main NUC-style aluminum alloy case can probably deal with cooling without the vents, it's wiser to ensure alignment, just in case. Matching the acrylic end fascia panels is also part of the challenge here. While close to finishing assembly, instead of rushing to complete the DeskPi Pro, take a moment to work out the correct orientation of the interior PCBs, the case, and the acrylic panels. Moments later, you should have a Raspberry Pi desktop computer ready to boot [**Image C**]. ⏻

FAN CONTROL

Once assembled, the DeskPi Pro's adjustable fan requires some dedicated software. After the Pi is installed in the DeskPi Pro and booted, the deskpi-config software provides seven options for detailed control over the cooling system. The software can be installed with:

```
cd ~
git clone https://github.com/DeskPi-Team/deskpi.git
cd ~/deskpi/
chmod +x install.sh && sudo ./install.sh
```

To run the tool, use `deskpi-config`. The app is self-explanatory, although it's easy to be confused by the options without context. Four specific speed levels can be set: 25, 50, 75, and 100 percent. The problem is that without knowing what impact the 100 percent speed has, the figures are meaningless. As such, deskpi-config is best used purely for overclocking purposes. Adjusting the fan speed can have a considerable impact on maintaining a stable system. Other options are available in deskpi-config. You can turn off the fan, or set the fan based on the Pi's start temperature. Finally, there's the automatic fan control option. This should be the default option, so ensure that this is set if you're not overclocking your device.

BUILD IT

ZAK STOREY, EDITOR-IN-CHIEF. **SAM LEWIS**, STAFF WRITER

AMD vs Intel Build Off!

Red vs Blue, youth vs experience and an integrated graphics build-off for the ages.

LENGTH OF TIME: **1-2 HOURS**

LEVEL OF DIFFICULTY: **EASY**

THE CONCEPT

THERE'S NOTHING WE ENJOY more at *Maximum PC* than a good old-fashioned build-off challenge. In the world of absent GPUs and crypto-currency madness, however, the traditional Intel vs AMD "who can build a better productivity machine" argument just didn't hold much water. It's hard to recommend building a workstation PC if you can't buy the workstation parts.

So with that in mind, we decided to try a different take on that age-old fight.

This issue, we pit the best of integrated graphics against one another: AMD vs Intel; Red vs Blue; Market Leader vs Underdog. And, with Christian out of the office, young rookie Sam will take on old man Zak in a build-off battle for the ages.

Is this an unfair fight? Absolutely. In one corner you have Zak Storey, *Maximum PC*'s long-time team member and editor-in-chief, complete with 19 years of PC building experience, and no less than 81 individual PCs built under his careful eye. In the other corner, Sam Lewis, relative newcomer and *Maximum PC* staff writer, complete with a total of two PCs built in his short time on this prestigious title.

But arguably the far more important question is who will win the battle of the builds, and take the crown of integrated-budget-PC-that-doesn't-cost-as-much-as-a-full-GPU-these-days champion? Read on to find out.

AMD BEHEMOTH

ALTHOUGH THE PHANTEKS P400A is a pretty slick-looking case, the build's attention isn't strictly focused on this or the machine's looks for that matter. We're sorry people, there is no off-the-wall flashy RGB here. The battle's main focus is on which is the better chip to side with for an integrated graphics rig, AMD or Intel? Yes, it's an age-old debate between AMD or Intel, much like the great PlayStation or Xbox wars of yesteryear.

We get it, it's not always a clear-cut verdict either. There may be many pros and cons of both and that's what we are hopefully going to explore with this build-off. We are hoping to show that you can get a decent gaming experience without the need for GPUs or hefty AIO coolers—and demonstrate the differences between an AMD or Intel build with this format applied. Of course, we aren't expecting 4K with the sliders on full whack here, but we should get Full HD gameplay with steady decent frames.

The AMD Ryzen 7 5700G chip we have should put up a good fight in this battle, it's probably one of the best choices for an AMD chip without the use of discrete graphics. This eight-core 16-thread chip is AMD's first 7nm 'Cezanne' Zen 3 APU (accelerated processing unit). It comes with a 3.8GHz base and a 4.6GHz boost clock. Like all Zen3 chips, the interface steps up from DDR4-2933 to DDR4-3200. With the integrated GPU, this will help boost gaming performance. For AMD processors, RAM speed matters.

The best you can really get is 3733MHz sticks as the chip's memory controller cut off at that speed, but they aren't exactly the easiest to find at the moment. We have gone with two 8GB 3600MHz Crucial Ballistix RAM sticks, which will be more than good enough to get fast memory speeds for our machine.

Although a specific price wasn't the MO for the builds, we have tried to keep things on the budget to a mid-range scale. The lack of GPUs should certainly help with this, although prices are slightly better than they were a few months ago. This should be an interesting challenge and we are excited for the outcome and what we can achieve through processors with integrated graphics.

INGREDIENTS

PART		STREET PRICE
Case	Phanteks Eclipse P400A	$75
Motherboard	Asus TUF Gaming B550M-Plus (Wi-Fi)	$162
CPU	AMD Ryzen 7 5700G	$359
Memory	16GB (2x8GB) Crucial Ballistix 16 DDR4-3600 CL16	$82
Storage	Western Digital Black SN750 1 TB M.2 PCIe 3.0 SSD	$126
PSU	Corsair CV 450 W 80+ Bronze	$45
Total		$849

1

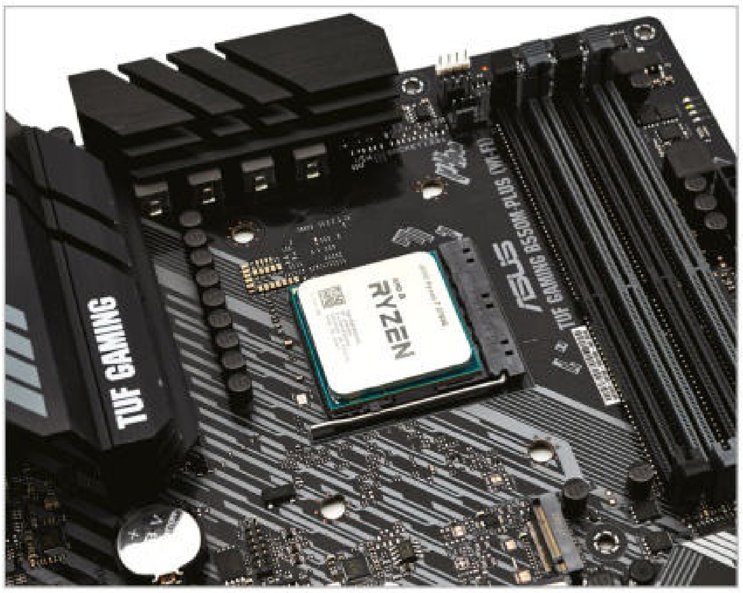
THE BAREBONES

THERE IS NO CHANGE HERE with the first step for both of our machines. It's off with the panels for this Phanteks P400 on the AMD build. It's great to see exactly what you are working with and give yourself as much room as possible. The tinted glass panel comes off easily once the four corner screws are removed. Thankfully for this case, they aren't as fiddly as they often are on PC cases. Speaking of the devil, two of these more fiddly thumb screws are found around the back securing on this panel. Our advice, use a screwdriver for these ones. For the front panel, you need to give it a hard pull from the bottom to pop it off. It's always scary the first few times but don't sweat—it should be fine, fingers crossed.

2

IN GOES THE CHIP

WE NOW TURN OUR ATTENTION away from the case and to our motherboard and more precisely, to the AMD chip itself. Like an Intel processor, the AMD chip has a tiny arrow on one corner that will align with an arrow on the mobo. First, though, we need to lift up the retention arm by pushing it down and outwards slightly before placing the chip down. Once this arm is up, we can now align the processor in place and rest it down. Always be careful here—pick it up by its sides and avoid touching the bottom pins. Then, secure it in place by lowering the retention arm back down. Lovely job.



3

GET CHILL

As integrated graphics are one of the main talking points of this build-off, the CPUs come with designated coolers. It's no real difference to fitting an AIO cooler, just with a lot less flapping around trying to fit in the radiator and extra fans. First, we need to secure the backplate onto the motherboard. After this, we need to apply a pea-sized drop of thermal paste onto the CPU, and gently align the cooler on top giving an even pressure. Once the screw holes are in the right position, tighten them up corner to corner to ensure an even tension. Right, up to speed? Before we are done with this, plug in the CPU cooler fan cable into the mobo. And that's it, for now.

4

INSTALL MEMORY AND STORAGE

Thankfully, these builds without GPUs and AIO coolers are generally less of a brain-bashing experience and this next step is one of the easiest. We now need to add the memory and storage. First, the RAM sticks slot in by releasing a clasp on the top and pushing in. It will only go in one way so check the bottom groove aligns properly. Also, if you are using two sticks like us, you must check the mobo's manual to slot them into the correct DIMM slots. As for the SSD, this slides into the connector at a 30° angle. Then a tiny screw secures it onto the mobo. We mentioned how easy these steps are, but this can be a little fiddly and brain-frying, oh the irony!

5

ALL ABOARD

What's a PC case without a mobo, you ask? Pretty useless, so let's get this installed. To make life a little easier, we connect up the main CPU cable first from the PSU. This is in the top left corner of the board and is a tight space to connect after installing the mobo. We also clip the I/O shield into the case before angling the motherboard in place ready for screwing. There are eight screw holes to secure the board into the case, but don't worry if some are too awkward to reach, as long as the screws are spread apart and the tension isn't just in one corner. After this, we connect up the power switch motherboard cable into the pins at the bottom of the board. This again is pretty fiddly—it's a running theme with PC building, but all part of the fun! Just be careful not to bend any pins as they are pretty delicate.

6

PSU POMP

To finish off this build, we need to add the PSU. This Corsair CV450 unit has one single exit port out the back where all the cables come from, so no independent cables here. Because this is a lighter build with no GPU and AIO cooler, we only need to connect the 24-pin and USB cable as we have already connected up the CPU one earlier, no SATA or PCIe here folks. The case has decent cable management at the back and enough room behind the PSU to store excess cables. We fed the two cables we needed through some rubber slots to the front and clip them into the board. Then using four screws, we secured the PSU into the bottom of the case, and hey presto, the PC is ready—nearly. We do a bit of cable management with the cases' velcro straps, then pop on the side panels, tighten them up, then pop on the front of the PC.

INTEL BUILD

YOU KNOW, the Intel Core i5-11600K has been in a lot of our builds lately. It's one of those chips that is handy to have and sits on the cusp of pretty much every area when it comes to a blue build like this. For instance, we originally considered running the Core i5-11400 instead, but the graphics are a step down (HD730 instead of HD750). Go any higher, with a Core i7 or Core i9 for example, and you don't really gain anything from an iGPU perspective, outside of increased core count (and cost).

It's funny, because back in the day, from Sandy Bridge all the way up to the 6th series Skylake parts, it was almost a cliche for tech journalists to say "Unless you really need hyperthreading, get an i5!". AMD came in and ripped up the market with ridiculous core counts and hyperthreading throughout, and it changed the very notion of what sort of chip you should get.

But now, with AMD's core count peaking, and Intel catching up and matching its feature sets (this hex-core features hyperthreading for 12 threads total, and oodles of IPC performance, too), we're sort of back to where we were, at least for recommendations on Intel anyway. Unless you really need those extra cores, the i5-11600K is a darn fine chip.

The only downside to the Core i5-11600K compared with the chips of yesteryear, is the fact it needs a decent cooler. This is exactly what prompted our next investment, the be quiet! Dark Rock TF 2 CPU cooler. It's a low profile, all-black little number that packs in some serious TDP alleviation with an epic fan too.

Pairing that with a Corsair iCUE 220T RGB case, complete with three intake fans, an MSI MAG B560M Mortar mobo, 16GB of Corsair Vengeance LPX (a trusty favorite), and of course, 1TB of pristine PCIe 4.0 M.2 storage (something our AMD Ryzen 7 5700G, just can't match amazingly), and what you're left with is a souped-up Team Blue iGPU machine, ideal for work and light play, for just under $1,000.

Is there anything we could have dropped from this build? Of course, there is. But we'll get to that later.

INGREDIENTS

PART		STREET PRICE
Case	Corsair iCUE 220T RGB Airflow	$115
Motherboard	MSI MAG B560M Mortar WiFi Micro ATX	$160
CPU	Intel Core i5-11600K	$270
CPU Cooler	be quiet! Dark Rock TF 2	$94
Memory	16GB (2x8GB) Corsair Vengeance LPX DDR4-3200 CL16	$74
Storage	1TB Western Digital Black SN850 PCIe 4.0 M.2 SSD	$180
PSU	be quiet! System Power 9 CM 500W 80+ Bronze	$85
Total		$978

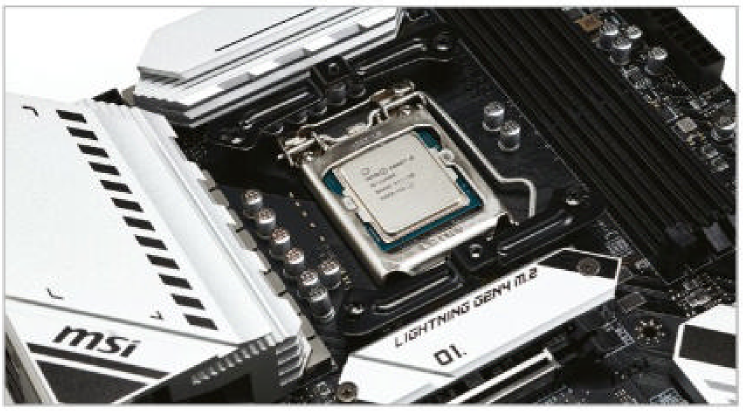
1 PANEL STRIPDOWN

AS EVER WITH OUR BUILDS, we start by stripping and removing every element of the case that might get in the way during the build process. This means removing the tempered glass window, rear panel, any fan filters and meshes, and the front panel too. You can also take the opportunity to remove the hard drive caddy if you don't intend to use the old 3.5-inch standard drives, as it will give you more space to maneuver in the bottom of the case when installing the power supply. This isn't the first time we've used this chassis, as we notice that two of the PCIe slot covers have been removed prior to this build. An ominous metaphor for the GPU industry as a whole right now, we feel. Missing.

2 MORTARING ALONG

WE'RE GOING TO PREP most of this build outside the case. It isn't absolutely necessary but makes things easier when you're installing coolers, backplates, and M.2 drives, as there's nothing getting in the way between you and the motherboard. First up is the most delicate part of the build, installing the processor. We're a little jealous of the AMD procedure—Intel's LGA processors have pins situated in the socket, rather than on the processor. To install it, lift up the retention arm on the right, carefully raise the bracket, and lower the processor into position.

There are a few ways of aligning it, either with the processor's writing reading left-to-right (as below), or by the gold triangle on the bottom left of the processor. Once in place, lower the bracket down and under the Torx screw, before securing the tension arm back into position. The plastic cover will pop off and you're done.



3

ALL THE WAY UP TO 11

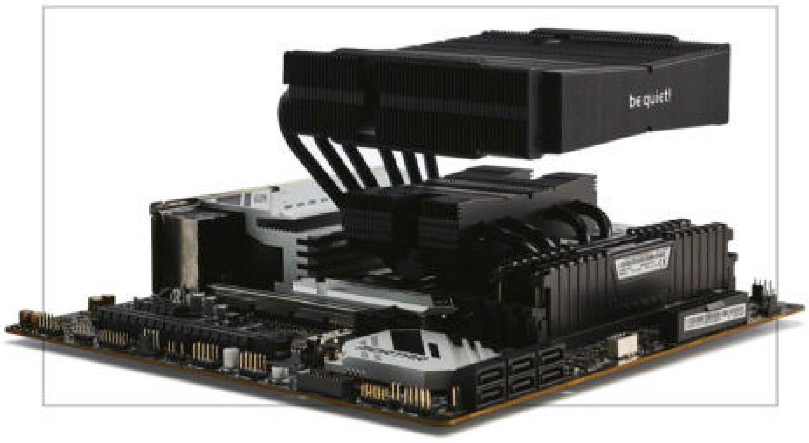
WE'RE NOT SURE what a Lightning Gen4 M.2 slot is, but if it's anything like a PCIe 4.0 M.2 slot, then this thing is going to be super quick. The one big advantage we have over our AMD counterpart is that the Core i5-11600K supports PCIe 4.0 as standard, unlike the G series Ryzen chips. That may make it pricier, but the speed exerted by these drives is next level, and worth it for production work. To install our M.2 drive, we simply remove the two screws on either end of the topmost M.2 slot, lift off the heatsink, and then insert our M.2 drive into the slot, being sure to match up the notch with the drive. Then once in place, we peel off the protective film from the thermal pad, and place it back over the M.2 and replace those two screws.

LIGHTNING GEN4 M.2
01.
MORTAR

4

QUIET!

ONCE THE DRIVE is in place, we move on to the DDR4. Unlock the clips at either end of the slots you want to use (alternate ones), then carefully slot our DIMMs into place, making sure to line up the notch on the bottom of the DIMM with the notch in the slot. Then it's on to the cooler. Be quiet!'s designs are always impeccable when it comes to providing ample cooling mixed with a hefty dose of style and the TF 2 is no different. This semi-low profile cooler comes with two fans (though we're only installing one) and is relatively easy to fit. We grab the Intel backplate and brackets, insert the standoff mounts, slot it through the motherboard, secure the two small brackets on the other side (remembering the plastic spacers). We apply a splodge of thermal paste to the processor, place the cooler on top, lining it up with the screw holes in the brackets, then secure it with a screwdriver.



5

CLEAN INSTALLS

NEXT ON THE LIST was installing the mobo inside the chassis. Now, admittedly, we had a bit of a problem here. The case has been used before, during a review a year or so ago. Sadly that meant that the accessory box was missing when we came to the build. A quick hunt around the *Maximum PC* studio hardware stash turns up a Phanteks screw box (the irony isn't lost on us), with just enough screws to secure the motherboard into position.

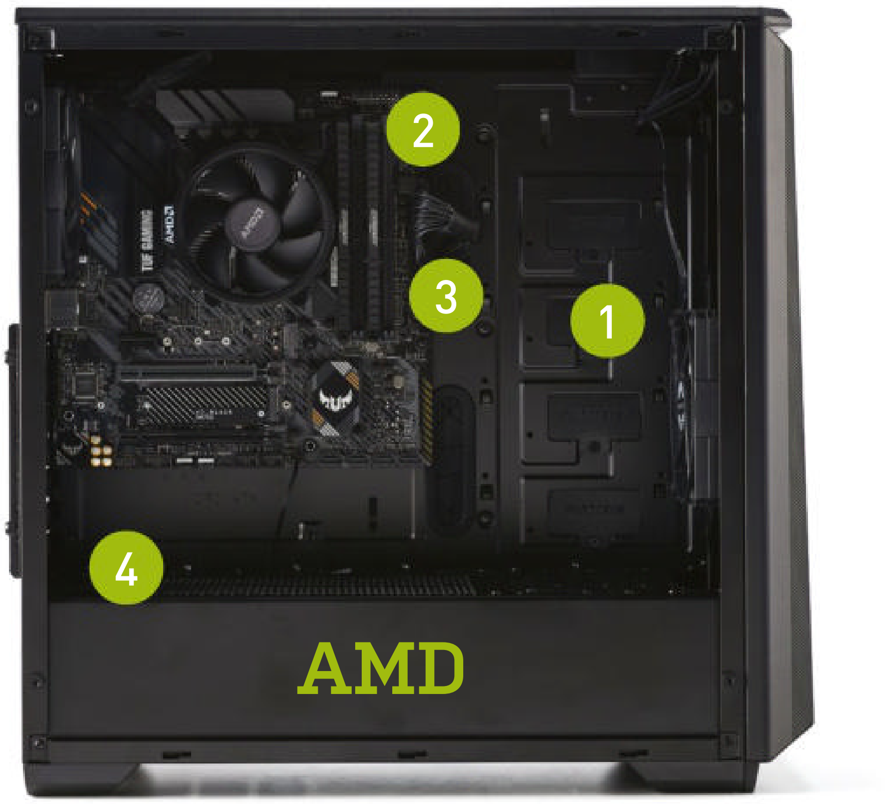
Laying the case on its side, we line the motherboard up with the stand-offs and then secure it in place with the correct screws. If you're planning on moving your system around a lot, make sure you install all of the screws. However, if it's just going to stay in your house, you can get away with doing four or five screws and it shouldn't be a problem.

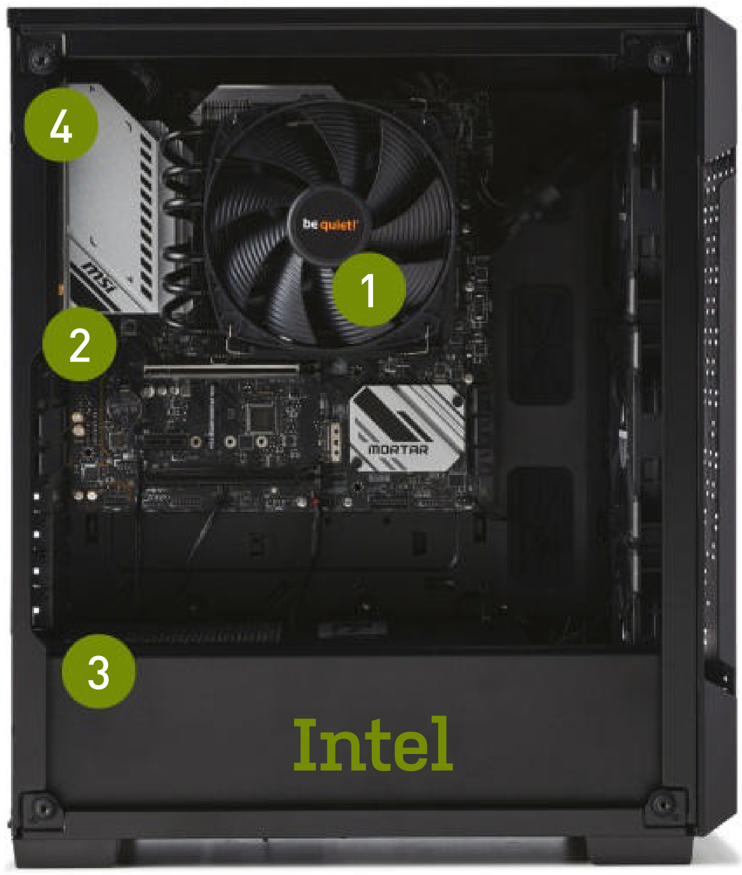
6

FAN...TASTIC

WE'VE SKIPPED A STEP here visually, the power supply installation. In short, we secure the PSU in the back of the case, thread the cables throughout the chassis and plug them in. For this build, we need the 24-pin mobo power to the right, the 8-pin EPS (or CPU) power in the top left, and a SATA power at the back for the RGB fans.

Next, we install our front I/O headers, consulting our motherboard manual to find the correct position for the pins. Now, on to the fan, which can be tricky. We attach two metal clips to the sides of the fan, position it over the top of the cooler, then carefully hook the clips around the cooler. It pulls tight and keeps the fan in position and though it's not the most graceful solution, it's lightweight and doesn't impede airflow. Once it's on, plug in the fan cable to the CPU fan header on the board and we're done.





1 With no GPU and AIO radiator cooler, the rig looks clean yet we can't help feeling that it's a little empty.

2 If we were to do this build again, we would probably make the most of all the DIMM slots by adding another two sticks of 8GB RAM.

3 Thanks to the Phanteks' design, the rubber cable holes are in the perfect position to neatly feed our 24-pin and USB cables right to the mobo.

4 It would also be nice to add some lighting to the case. We're happy with how it works, but let's just say it's a bit bland.

1 Be quiet!'s Dark Rock TF 2 is a monster. We only installed one fan, but you could install a second one for extra airflow.

2 The MSI B550M is a great motherboard, with one major flaw—it lacks lots of fan headers. You could buy a fan-splitter cable to power two fans off one header.

3 With a 500W PSU tucked away under the floor here, there's plenty of headroom to install a GPU in the next two years once they become available again.

4 In this setup, the case is mainly positive pressure, but adding an exhaust fan would help keep internal temps cooler.

THE CONCLUSIONS

SAM LEWIS: Piecing this machine together was a walk in the park. Fewer parts doesn't always equal easier, but Team AMD had luck on our side. No traditional radiator and cooler gave us more space to work with too. Compared with a few recent ITX builds, it's like swapping from a Mini Cooper to a Dodge Ram. The case is pretty large, but we love it. We know we said it wasn't about looks but if we were to rebuild, the RGB variant of this case would be a better choice—it's a bit empty in there and it needs a little something extra.

The only issue we had with this build was securing the CPU cooler onto the backplate, as it was a bit tight. We had to apply a bit of pressure to the backplate to get at least one screw in to finish the rest off slowly, go diagonally, take your time. Ideally, we don't want to put this pressure on the motherboard, but we also kind of needed the cooler. So, after some long hard thinking, we tried our luck.

After that, we had to get this thing up and running. With nothing coming up on our monitor, we knew we needed to update the mobo's BIOS. Version 2423 was downloaded onto an empty FAT32 USB drive, we ran the renaming program, deleted the unnecessary files, and put it into the BIOS FLBK USB port on the back of the PC. Then we held the button down for a few seconds until it started flashing and let it do its thing. Once it booted, we loaded the Windows media creation tool onto another USB stick as per usual and got the OS installed too.

As a whole, this was a successful procedure with only a minor hiccup with some short screws. Not bad, right?

ZAK STOREY: I do love the smell of silicon in the morning. Especially when it goes pop. Actually no, it's the worst. That burning smell screams "dead hardware" and sadly on power-up, that's exactly what we experienced with this build, Just before the end of the shoot, we powered the PC on, just to see what it looked like with these three fans in the front of the case and, to our surprise, nothing lit up. The power was on, the PC was running, but no light.

Fast forward five minutes, and a bit of fiddling around later, and still nothing. Then, silence. The PC came to a standstill, fans refused to spin, motherboard refused to light up. Nothing, no power-button wiggling, different kettle leads, or any of our usual tweaks helped. Then the smell arrived, that awful smell of burnt silicon, electricity, and water.

The culprit was discovered—a short-circuit on the RGB controller had burnt itself out, killing the power supply in the process. Fortunately, everything else was unharmed, but it just goes to show, leaving a once-tested case in a leaky, cold warehouse with an open box for a year, can sometimes lead to moisture build-up and eventual failure. Who knew? One new 500W power supply, and a lack of RGB later and we were good to go. You can have all the build experience in the world, but no matter what, there's always bound to be something that can catch you out. ⏻

LAB NOTES

CHRISTIAN GUYTON, STAFF WRITER

Going Mobile

Getting Prepped for a Hospital Stay

AS MUCH AS I'd like to say that I'm fully recovered, the old cancer is still kicking (in my bones, apparently) so I'm due to spend six weeks in hospital for a stem cell transplant. Fortunately, one of the perks of this job is regular access to cool hardware, so I've been prepping for my hospital stay by working out what tech to take with me.

Of course, I'll be taking a laptop for gaming and catching up on streaming content (such as the excellent *Squid Game* on Netflix) but spending so much time in and out of chemo wards over the past year has forced me to get comfortable with portable gaming again. It's been a long time since I rocked a handheld; I was one of the few people who purchased a PS Vita, and my old Nintendo DS saw plenty of action back in the day.

Nowadays, your options for gaming on the go (or from a hospital bed) are limited. There's the Switch, which is great but comes with the caveat of limiting yourself to Nintendo-approved titles, and I've not been lucky enough to be blessed with an early-access Steam Deck, so I've cautiously ventured into the world of mobile gaming.

I got a new Google Pixel 5 last year and it turns out mobile gaming has come a long way since I last dipped my toe in; *PUBG* runs pretty well on my new handset, and I've even found some enjoyment in the somewhat baffling systems of *Genshin Impact*. More importantly, *Slay the Spire* and *Gwent* are available on Android, so my primal deckbuilding urges are sated.

Of course, my Pixel 5 needed a little support to become a proper gaming unit, so I've enlisted the help of peripheral manufacturer Gamesir. The F8 Snowgon is a nifty piece of kit that cools your phone with a near-silent RGB fan while also providing an analog stick and gamepad-esque casing. Gamesir also provided an F5 Falcon Mini, a set of clip-on triggers that help massively in shooters. I'm still in need of a new portable charger, but I'm more ready for a period of isolation than I would have been previously. And no, before you ask, I'm not buying Razer's weird mobile gaming thumb-socks.

Gamesir's F8 Snowgon makes mobile gaming that much more comfortable.

© GAMESIR

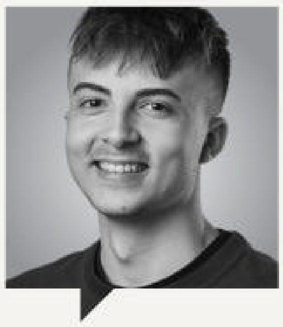
KRIS BUTTERILL

Contributor

Last time I looked, it was June and now October is slapping me in the face. That's what happens when both Intel and Asus ask you to build systems for promotional campaigns and you don't want to say no.

A monster build featuring a dual system, $20,000 of hardware, and housed in a back-to-back custom Raijintek Enyo was up first, followed by what seemed a basic build in a Lian-Li 011 Dynamic XL ROG Edition.

But the real pressure was standing face to face with the people who commissioned you to build them, and waiting for their facial expression to say either yes, we love it, or no, we hate it. Either they are really good at Poker, or the hours of hard work paid off!



SAM LEWIS

Staff Writer

Good news! I have progressed up the gaming timeline. The short and sweet of it is *Battlefield 4* has re-entered my life, but for the first time on PC. I last played it on the PS3, so a little time has elapsed since then. But, with the sliders right the way up and on an ultra-wide display, *Battlefield 4* still looks and plays great, even to this day.

I'm loving taking old games from my childhood and reliving them in playable graphics and frames this time around. Will we look at current titles in 10 years and marvel at how we used to put up with them? Cringing at *Far Cry 6*'s graphics seems like a petty crime right now, but who knows what we will feel in a decade's time?

Editors' Picks: Corsair Sabre RGB Pro Wireless Mouse

With a mouse this good, do the CPI and IPS stats matter?

TWO MICE in one issue? Yep, we've got a gluttony of the funky pointers this month. We've seen the "surprisingly good" (to quote Christian) Marsback mouse with its perforated form and tiny fan, and now, this plucky wireless number, the Sabre RGB Pro Wireless Champion Series.

We've already taken a look at the wired version, so I didn't think it was worth giving it the full review treatment. On paper, there isn't much of a difference between the two—both have the same ergonomic shape, feature Omron switches rated for 50 million clicks, on-board memory profiles, RGB, and can theoretically be used in a wired mode (the wired version's cable is about 12-inches longer). They are roughly the same weight, with the wired variant weighing in at an impeccably light 2.61oz (74g) and the wireless version clocking in at an incredible 2.78oz (79g).

The primary differences between the two come in the form of the sensors used (and obviously the price tag). The wired edition features the PixArt PMW3392 sensor, it's a slightly updated version of the standard 3390, configured to Corsair's demanding 8000Hz hyper-polling requirements. It clocks in a max CPI of 18,000, is capable of handling up to 50Gs of acceleration, and has an IPS rating of 450 before it starts losing accuracy.

For $60 that's impressive, and it feels it too. It's been a daily driver of mine for some time and the combination of its lightweight design and responsive and accurate sensor has somewhat muted my enjoyment of the new M65 Ultra, which is a personal favorite design, (it's basically ruined my taste in mice. I used to like the heavy mice, now I don't!).

The Wireless version costs $110 and features Corsair's own branded Marksman 26K sensor. This is, according to our research, a slightly tweaked variant of the PixArt PAW3393 wireless sensor. Designed specifically for super low power usage on wireless mice, this has been modified by Corsair to provide a higher CPI rating (26,000 hence the name), higher IPS capacity (650 to be precise, almost 37mph), and a higher report rate too. It's a bit of a balancing act, as it has to draw limited power through Slipstream's 2.4GHz wireless connection, while also providing a high polling rate, and remaining lightweight at the same time. It's highly responsive and accurate, and during my time with it, I saw no ghosting or accuracy artifacts whatsoever, which is to be expected from a $110 mouse.

What's more impressive, especially for a wireless mouse, is the weight, 2.78oz. That's so light, it's ridiculous. You have to remember this thing has a battery in it and can quite happily sit there in active use for a week or so and still not require a recharge. Admittedly, that's with the RGB disabled, but with it on, you're still looking at three or four days, which is impressive.

However, I'm starting to wonder, given how good mice sensors are getting, whether the CPI requirements and improvements are necessary. Maybe we should be working on power and weight savings, rather than increasing CPI and IPS exponentially? When was the last time you moved your hand at 37mph? Even astronauts returning to Earth only experience 3-5Gs. What we need is a high-performance wireless mouse with 30 days of charge and some efficient RGB lighting. A boy can dream, I suppose. **–ZS**

$110, www.corsair.com

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Reviewed...

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80 Corsair Xeneon 32QHD165

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88 Logitech StreamCam
89 Marsback Zephyr Pro
90 Deathloop
92 Asuswrt Merlin vs Netgear Nighthawk

ASRock RX 6700 XT Phantom Gaming OC

A good GPU in a mediocre card

FAST. MYSTERIOUS. Unbeatable. So proclaims the writing on the back of ASRock's RX 6700 XT Phantom Gaming OC card. We're not sure where the mystery comes in, unless it's referring to actually finding one for sale. Regardless, AMD's RX 6700 XT delivers a healthy amount of performance at a theoretically reasonable price. ASRock's Phantom Gaming variant, not so much.

ASRock mostly plays it safe with the Phantom Gaming line, with a triple fan design and a fair amount of RGB lighting, which can be disabled at the flick of a switch. The card is longer and thicker than the reference design, but the added cooling allows for higher TDPs and lower temperatures, with a modest factory overclock tossed in for good measure.

The boost clock of the reference card is 2581MHz, and ASRock cranks that all the way to… 2622MHz, a 1.6% overclock. The power limit is also extended by 20W, which should also eke out a bit more performance, though if you want access to the full out-of-the-box overclock, you'll need to install the ASRock Tweak software and select OC mode.

Unfortunately, the performance ends up being a few percent lower than AMD's reference card. It's difficult to explain, but after multiple retests of both the ASRock and AMD reference cards, the numbers don't lie. Ultimately, what you get is a performance that's roughly equal to the Nvidia RTX 3060 Ti in overall performance—it's faster in AMD-friendly games, such as *Assassin's Creed Valhalla* and *Borderlands 3*, and slower in just about any game that makes use of the ray-tracing capabilities on the latest GPUs. That's without DLSS, incidentally, though also without FSR. Either way, Nvidia still rules the roost when it comes to fancy in-game lighting effects.

Which card should you buy, given the choice between the RX 6700 XT, RTX 3070, and RTX 3060 Ti? If we could find the AMD card for $480 and the Nvidia cards for $500 or $400, respectively, we'd give Nvidia the edge—though the RX 6700 XT does win out in the memory department, where it has 12GB compared to 8GB on Nvidia's cards. In practice, you'll probably need to shop somewhere like eBay to procure a card, where prices for the RX 6700 XT currently average around $750—about $200 more than the MSRP.

That might seem terrible, but in today's market, it's about as good a deal as you're likely to find. For example, Nvidia's RTX 3060 isn't much cheaper at $700 and delivers much lower performance (except in ray tracing). The RTX 3060 Ti and RTX 3070 meanwhile sell for around $900–$1000, more for the non-LHR models that do better at Ethereum mining. AMD doesn't try to limit mining performance, but thanks to the 192-bit memory interface, it's generally not as attractive as the Nvidia alternatives, which keeps pricing a bit lower.

In effect, the RX 6700 XT represents the best of the worst when it comes to current graphics card values. If you're looking for good value without any caveats and provisos, it doesn't exist right now. Maybe we'll see prices return to some semblance of normalcy in 2022—Lisa Su, the CEO of AMD, said she expects the chip shortages to ease by "late 2022," but that's still a long way off.

But some people still need or want a new graphics card. The RX 6700 XT does better than most other options, even if it's technically a high-end card being sold at extreme enthusiast pricing. Remember when we could get the fastest GPUs for under $700? Today, $700 will only get you a third or fourth string option, like this ASRock card that gives you higher pricing and worse performance. **–JARRED WALTON**

RAM BENCHMARKS

	ASRock RX 6700 XT Phantom Gaming OC	AMD Radeon RX 6700 XT	Nvidia GeForce RTX 3070 FE	Nvidia GeForce RTX 3060 Ti FE
8 Game Average (fps)	80/59	82/60	**90/68**	82/60
Assassin's Creed Valhalla (fps)	**108**/78	105/**79**	80/66	75/61
Borderlands 3 (fps)	126/86	**128/88**	116/85	103/74
Control (DXR)	44/28	46/28	**69/45**	63/40
Cyberpunk 2077 (DXR)	29/18	29/18	**48/29**	42/26
Dirt 5 (fps)	111/88	115/92	**117/97**	113/86
Horizon Zero Dawn (fps)	113/94	121/97	**121/98**	112/89
Metro Exodus (fps)	87/70	89/71	**99/79**	87/69
Red Dead Redemption 2 (fps)	93/77	93/77	**97/80**	87/72

Best scores are in bold. All testing conducted with a Core i9-9900K, MSI MEG Z390 ACE, 2x 16GB DDR4-3200 CL16, 2TB XPG 8200 Pro M.2 SSD, Thermaltake Toughpower GF1 1000W. Scores are average framerates at 1080p/1440p.

VERDICT
6

ASRock RX 6700 XT Phantom Gaming OC

+ MYSTERIOUS Decent performance; 12GB VRAM; nice RGB bling.

− BLUNT Still expensive; slower than reference; poor availability.

$480 www.asrock.com

SPECIFICATIONS

Architecture	Navi 22
Lithography	TSMC N7
Boost Clock	2622MHz
GPU Cores	2560
Memory	12GB GDDR6 16Gbps
TFLOPS FP32	13.4
Bandwidth	384GBps
TDP	250W
Connectors	1x HDMI 2.1, 3x DisplayPort 1.4

PHANTOM GAMING
ASRock
PHANTOM GAMING
PHANTOM GAMING

ASRock's RX 6700 XT Phantom adds bling, but the performance isn't as impressive.

Razer Blade 14 QHD

AMD CPU + Razer Blade 14 = razor sharp laptop

THE RAZER BLADE 14 has been referred to as a subtle beast. Indeed, the chassis gives little away, other than that it's clearly a premium laptop. But Razer is hoping that what lurks beneath the aluminum structure will lure gamers in. This time, Razer has introduced an AMD chip into the Blade 14—and not just any old chip, the AMD Ryzen 9 5900HX to be precise, a pretty mean processor for gaming. In this model, you can also find the range-topping GeForce RTX 3080. For a compact device, such as the Razer 14, this is a pretty impressive feat. So, let's see how well Razer has executed this idea and whether it is worth your time.

The laptop gives off a premium look and feel, with a build quality that's comparable to an Apple MacBook Pro. We're on team PC, of course, but that's a compliment for the Blade 14. There is no chassis creaking or screen wobble, and combined with the matte black design, it makes a great-looking laptop that's only 0.6-inch thick. The only branding is Razer's classic green LED emblem on the lid and a subtle logo under the screen. Above the screen is a 720p webcam with microphone, which is handy for when on the move. It's no showstopper but will be fine for hopping on a Google Meet call.

The screen also gets a thumbs up. Its classic 14-inch size is ideal for portability and compactness, while still being a decent size when gaming on a desk. Sure, a 15-inch display is easier on the eye and better for gaming, but this is a perfect size for throwing in a rucksack and taking with you on the move. To have desktop performance that you can carry around with you is quite impressive. The display has a high refresh rate at 165Hz to make everything a bit zippier. Even scrolling through the internet is a more enjoyable process with a fast refresh rate.

With its 2560x1440 QHD resolution, the Blade 14 has an impressive display. The color range is deep and rich without being too sharp. It's crystal clear for gaming, films, and other forms of procrastination. Of course, there is always room for improvement with an even higher refresh rate, but we are impressed with this screen. Razer's keyboards have only got better in recent years and while this isn't a clicky mechanical beast, it's comfortable for productivity-based work with plenty of key travel and feedback. The keys are backlit and controlled via Razer's Chroma lighting software. The trackpad is pretty large for a 14-inch laptop and does a great job as far as trackpads go, but we'd recommend pairing it with a mouse or a controller for gaming.

Connectivity is also good, with two Type-A USB and two Type-C USB ports that support power delivery and Displayport 1.4. There's also an HDMI port, audio jack, and a mains power delivery port. Battery life isn't the best, but with this laptop's internals, it's hardly a surprise. Without the power plugged in, you get a maximum of around two hours of game time when running at full whack. However, when you aren't gaming, it's adequate for most other tasks.

But running this thing on full whack is where the real magic is. It's a complete monster. Benchmarking at 1080p on ultra easily gave us fps ratings higher than 70 and games look and play superbly with these settings applied. You can get higher frames by running at a lower preset that will still look awesome on this panel. Though it is great for gaming, it is equally as powerful for productivity, this doesn't come as a shock, considering the super snappy CPU and GPU.

The Razer Blade 14 laptop ticks lots of boxes. It's a stylish, compact, and portable bit of kit that has a great build quality, snappy and high-resolution QHD display, and a huge amount of power packed into a thin chassis. What's not to like? Maybe the price. This range-topping RTX 3080 model costs $2,799, but that hefty figure gives you a great desktop experience in portable form. With the Blade 14, Razer has nailed most aspects of a laptop with this great all-rounder, but it comes at a price. **–SAM LEWIS**

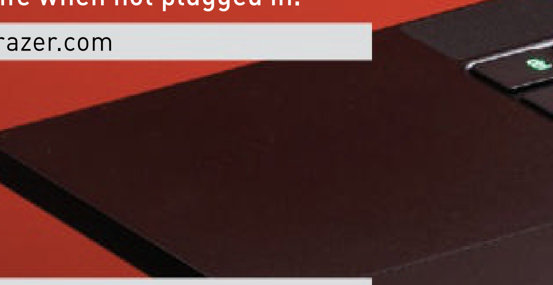
VERDICT
9
KICK ASS!

Razer Blade 14 QHD

➕ **BEST OF BOTH WORLDS** Hard hitting performance; snappy QHD display; clean design; compact form.

➖ **WALLET BURNER** Pretty expensive; poor battery life when not plugged in.

$2,799, www.razer.com



BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi (Index)	2,137	1,977 (-7%)
CrystalDisk QD32 Sequential Read (MB/s)	3,595	3,572 (-1%)
CrystalDisk QD32 Sequential Write (MB/s)	3,107	2,978 (-4%)
3DMark: Fire Strike (Index)	20,529	20,516 (0%)
Rise of the Tomb Raider (fps)	107	110 (3%)
Total War: Warhammer II (fps)	83	87 (5%)
Tom Clancy's Ghost Recon: Wildlands (fps)	61	72 (18%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our gaming laptop zero-point is the ASUS ROG Zephyrus G15, with an AMD Ryzen 9 5900HS, Nvidia GeForce RTX 3080 and 32GB of DDR4-3200. All game tests are performed at 1080p at the highest graphical profile.

SPECIFICATIONS

CPU	AMD Ryzen 9 5900HX @ 3.30GHz
Graphics	Radeon Graphics, NVIDIA GeForce RTX 3080 8GB
RAM	16GB DDR4 3200MHz
Screen	14" QHD @ 165Hz 2560 x 1440
Storage	1TB SSD
Ports	2 x USB 3.2 Gen 2 Type-A Ports, 2 x USB 3.2 Gen 2 Type-C with Power Delivery and DisplayPort 1.4, HDMI 2.1, 3.5mm headphone/microphone combo port, charging supported with 20V USB-C chargers with PD 3.0
Connectivity	Wi-Fi 6E (802.11ax), Bluetooth 5.2
Weight	3.92lbs
Size	0.66 x 8.66 x 12.59in

You wouldn't think such a sleek laptop could house a behemoth RTX 3080 inside so discreetly.

Corsair's new 32-inch 1440p gaming panel is seriously pricey

Corsair Xeneon 32QHD165

Does premium-priced 1440p gaming make sense?

NEARLY 800 BUCKS for a 1440p panel? In 2021? This thing needs to be very good indeed. Enter the new Corsair Xeneon 32QHD165, a 32-inch IPS gaming panel with a 1440p native resolution, 165Hz refresh, and sub-3ms pixel response.

On paper, that's not a hugely impressive core feature set, especially for the money. But there's more to a subjective gaming experience than mere numbers. Some things require a more subjective, qualitative assessment. But, let's cover the 32QHD165's speeds and feeds. The 1440p resolution translates into 2,560 x 1,440 pixels on an 16:9-aspect panel and sub-100dpi in terms of pixel density. An Apple Retina-style display this isn't.

Speed-wise, it has a 165Hz refresh and response of below 3ms by the grey-to-grey standard and 1ms in the alternative MPRT metric. VESA DisplayHDR 400 certification ensures peak brightness of 400 nits, though there is no local dimming and this is not a true HDR display. Static contrast, meanwhile, is pegged at the usual 1,000:1 for an IPS panel.

As for accuracy, Corsair quotes 98 percent coverage of the DCI-P3 gamut, which is impressive for a gaming-biased monitor and in part a function of the use of quantum dot tech in the Xeneon's backlight. It also has adaptive refresh in both AMD FreeSync Premium Certified and Nvidia G-Sync compatible varieties.

Inputs are covered by a pair of HDMI 2.0 ports, a DisplayPort 1.4 socket, and USB-C with DisplayPort 1.4 alt mode and power delivery. The latter is limited to just 15W of power—we'd rate 65W as the bare minimum for a desktop replacement laptop and 100W as preferable.

For the record, the HDMI ports are limited to 144Hz and support a so-called "console mode" that downscales 4K to 1440p. For now, that's of most relevance for the Sony PS5, which doesn't support 1440p. But suffering the GPU load of running at 4K only to downscale that to 1440p doesn't make a whole lot of sense.

The whole thing is wrapped up in a well-engineered chassis complete with a die-cast aluminum stand with height, tilt and swivel adjustment. In terms of ergonomics, Corsair deserves praise for the clarity and logic of the Xeneon's OSD menu, it's a cut above the norm.

But is the image quality exceptional? Strictly speaking, no. That's not to say this screen is poor—the core image is punchy, vibrant, accurate, and well-calibrated when using the preset modes, such as sRGB. It's a quick panel that does justice to its on-paper specs and happily turns its hand to pretty much any type of gaming. Online shooters, such as *Apex Legends*, have plenty of speed and little latency. Graphics fests, such as *Cyberpunk 2077*, have basic HDR support and decent overall visuals, while 1440p gets the job done for *Total War*-style strategy titles.

However, the Xeneon 32QHD165 struggles to justify that premium pricing. It can't compete with the stunning visual detail of a 4K monitor. Esports addicts who care about the last word in latency will be unimpressed by the 165Hz refresh. And if you want truly eye-popping HDR drama, it's simply not on offer here.

In the real world, for most gamers, 165Hz is plenty. As an all-round gaming panel that delivers decent visual detail without hammering your GPU, the Xeneon's 1440p res also makes sense. But to put its price into context, the LG UltraGear 32GP850-B goes for $599, while cheaper alternatives based on VA rather than IPS panels start for as little as $300. For us, the price needs to be nearer $600 than $800 for the overall proposition to make sense. **–JEREMY LAIRD**

VERDICT
8

Corsair Xeneon 32QHD165

⊞ **PENTHOUSE SUITE** Really nice engineering; great all-round performance and image quality.

⊟ **ROADSIDE MOTEL** Too pricey for a 1440p panel; USB-C only delivers 15W charging

$799, www.corsair.com

SPECIFICATIONS

Panel size	32-inch
Panel type	IPS
Resolution	2,560 x 1,440
Brightness	440 nits
Colour coverage	98% DCI-P3, 100% Adobe RGB
Refresh	165Hz
Contrast	1,000:1
Response	1ms MPRT (<3ms GtG)
Inputs	2x HDMI 2.0, DisplayPort 1.4, USB-C with DP 1.4 Alt Mode

Netgear Nighthawk RAX200

Pricey Networking Supremacy

OK, SO IT MIGHT mildly resemble Emperor Palpatine's personal shuttle (the Lambda-class T-4a, not the Sentinel-class, that thing sucked), but Netgear's Nighthawk RAX200 is an absolute monster in the world of personal networking. Staying with the *Star Wars* analogies, it's like the Empire took the Deathstar, merged it with an Imperial Class Star Destroyer, and then condensed it all down into something the size of a Millenium Falcon.

And boy, is it expensive. Yep, this thing is $500 of routing nuttiness that leaves us with mixed emotions. First, let's start with the positives. It's a WiFi 6, tri-band router, complete with 12 streams, 2.5Gbps Ethernet ports, Multi-gig internet ports (via link aggregation), VPN support, eight WiFi antennas, beamforming and MiMO as standard, 2x USB 3.0 ports, a quad-core 1.8GHz processor, 882MB of usable RAM, 512MB of flash storage, a surprisingly potent cooling fan, and enough additional features to make you weep (although some of those are locked behind paywalls). There's a lot here, in fact, we could spend the rest of this review ticking off the feature list.

As far as performance goes, it's impeccable too. Compared to our test unit (the Asus RT AX88U), Ethernet performance was on par, tapping out with an impressive 149.82Mb/s down, and 19.23Mb/s up, slightly higher than the RT AX88U's 147.32Mb/s down, and 18.15Mb/s up on the day. And in the WiFi testing, using WiFi 6 on a Samsung Galaxy S21 Ultra, one floor up, and an identical server choice on speedtest.net, the RAX200 managed 128Mb/s down and 18.0 Mb/s up, well within the margin of error compared with the AX88U's 129Mb/s down and 18.1Mb/s up. A marked improvement in comparison to the AX5400 WiFi 6 router we reviewed in the previous issue.

So a close one then? And given the price difference between the two, perhaps less impressive than first assumed? That said there are some real-world problems that we've been seeing with the Asus AX88U that the Netgear seems to deal with far better. For instance, our IOT devices (Nest cameras, smart doorbells, and smart plugs) were more responsive. The outdoor cameras in particular loaded immediately on demand, unlike with the Asus, where they'd often freeze and fail to load an image at all, even on low-bandwidth settings. TV streaming also never dropped during our time with it either unlike the Asus. Loading webpages was noticeably faster as well, and we had a strong WiFi 6 signal a good 20 feet away from the router, outside of the property, stuck between three brick walls and a refrigerator. In fact, it was so good that we actually bumped up the resolution on the cameras to max instead of low. Neat.

Now that's out of the way, let's talk about the negatives. Setup. Oh boy, what a mess! Frustratingly, the main way of setting up the RAX200 is via the Nighthawk app, which took about an hour to get connected with our internet. Netgear pushes the app hard, in fact, there are even adverts for the app on the desktop browser login, which is frustrating as a power user.

You can do everything that you can on the app on the desktop, but everything's just a bit cleaner, and better laid out on your phone. The only downside is if you have a long-winded username and password for your PPPoE internet login, manually entering that during the setup process via the app is also frustrating.

The RAX200 also comes with an additional extra, again tied to the app, involving security—a free month's trial of Netgear Armor powered by Bitdefender. This yearly subscription scans any added WiFi devices to detect vulnerabilities (at which point, it will drop a notification on your phone, and ask you to update the device) and blocks malicious attacks for $70 a year (without a discount).

That feels a bit steep, especially as Asus offers this as standard with most of its router solutions via AiProtection. Of course, it still has parental controls, blocks, and firewalls in place as standard, but if you want that additional automated VPN and scanning layer you need to pay, which feels a bit cheap for a $500 router.

Once set up and configured, the RAX200 is an incredible piece of kit. Netgear has clearly put a lot of emphasis and development time into the App environment. We're just not sure, for power-users (and let's face it, if you're investing $500 in a router, you probably are one), the default setup guide should be pointing you towards the app first when a perfectly good rig will get the job done four times as fast. **–ZAK STOREY**

VERDICT

9

Netgear Nighthawk RAX200

➕ **STEPHEN HAWKING** Incredible performance; strong range; broad feature set; potent app.

➖ **HAWKEYE** Features locked behind subscription; setup process needs to be more flexible.

$500 www.netgear.com

SPECIFICATIONS

Wireless	2.4GHz AX: 4x4 (Tx/Rx) 5GHz AX: 4x4 (Tx/Rx) 5GHz AX: 4x4 (Tx/Rx)
Wi-Fi Encryption	WPA2-PSK [AES], WPA-PSK [TKIP] + WPA2-PSK [AES], WPA/WPA2 Enterprise, WPA3-Personal, WPA2-Personal [AES] + WPA3-Personal
CPU	1.8GHz Quad-core processor
RAM	822MB
Storage	512MB Flash
Ports	1x RJ45 WAN, 4x RJ45 LAN, 1x 2.5G Multi-gig, 2x USB 3.0

Dunnn dunnn dunnn dannnnn,
denn dunn dann denn dunn....

With some great cases from Lian Li already, the only worry is, what's next?

Lian Li Q58

Lian Li is at it again, this time taking on the SFF market.

BOTH INTEL and AMD-based ITX motherboards have come a long way in recent years and with M.2 based storage becoming so popular, it means that clean-looking SFF builds are appearing more and more, with the performance to match. To meet the surge in demand, we are seeing a whole load of companies pumping out matchbox-sized cases in 2021, taking advantage of the growing popularity of these builds. Gone are the years of oversized monster cases, it's the turn of the little guys to prevail.

Lian Li has been producing some amazing, functional, high-quality cases in recent times, and it is fast-becoming the case manufacturer that can't put a foot wrong. Its Q58 is the latest example of how to do things right, with little to no compromise on either form or function.

Even at first glance, you can instantly tell that the Q58 is a Lian Li case, with high-quality construction using aluminum, and tempered glass in a range of finishes for a contrasting two-tone design. At just 14.5 liters of capacity, it's amazing just how much you can squeeze into this case, even an ATX power supply should you wish to use one, up to 160mm. The attention to detail is excellent, there's space, somehow, for up to four externally mounted drives, including a tool-less hot-swappable bay for a 2.5-inch drive at the rear. Gullwing-styled side panels are unique to the Q58 and the debate that's going to rage on is what looks best, with the combination of glass and aluminum half panels at your disposal. Additional perforated aluminum panels are also available from Lian Li, should you want to remove the glass. Which is a nice touch.

In the box, Lian Li includes an optional mounting panel for ATX power supplies, and the modular construction allows for a range of final looks and configurations. Depending on the choices you make, water cooling to some extent is possible with space for up to a 280mm radiator in the top and a 120mm in the bottom. AIOs are going to feature a lot here, but a full loop is potentially possible, with some clever mounting and tube runs. Normally, running a GPU so close to a side panel is frowned upon, but here, with the ability to use the perforated panels or even a combination, it's certainly a case that you might want to consider.

With 320mm clearance and mounting for up to a three-slot card, most GPUs will have no issue sliding into place. Lian Li includes a riser cable with both Gen 3 and Gen 4 options available, so it's a headache you don't have to deal with down the road. But, I hear you say, what about RGB? Lian Li has thought about that too, with an included LED/fan hub that covers up to three PWM fans and three addressable headers, which can all be motherboard controlled. Front I/O includes an HD audio port, and both a single USB 3.1 Type C and a standard USB 3.0. Dust, what dust? Also included are two magnetic dust filters for the bottom of the case, they are easy to access and are more than capable of keeping your system clean.

Overall, the Q58 is almost perfect, it would be nice to see more color options than the now-standard black and white variations on offer, and the pricing is about right, depending on what version you are looking to buy. The Q58 with a Gen 4 riser is slightly more money, but the performance benefits in the coming years are worth the extra.

With some great cases from Lian Li already, the only worry is, what's next? How is the company going to develop something even better than its most recent releases? Whatever it has up its sleeve, it will need to be special, truly special. **–KRIS BUTTERILL**

VERDICT
9

Lian-Li Q58

➕ **ALBATROSS** Great design, ample airflow, Included riser at this price is epic.

➖ **CORMORANT** Black or white options only, No included fans.

$129.99 www.lian-li.com

SPECIFICATIONS

Motherboard Support	Mini-ITX
Fan Support	*SFX PSU Mode*: Top: 2x 120mm or 2x 140mm Bottom: 1x 120mm *ATX PSU Mode*: Top: 1x 120mm or 1x 140mm Bottom: 1x 120mm
Radiator Support	*FX PSU Mode*: Top: 1x 240mm or 280mm (Max length 315mm, or max 325mm if remove front SSD tray) Bottom: 1x 120mm *ATX PSU Mode*: Top: 1x 120mm Bottom: 1x 120mm
PSU Support	SFX/SFX-L/ATX (max length 6.2 inches)
GPU Clearance	12.5 inches
CPU Cooler Clearance	2.6 inches
Drive Support	*SFX PSU Mode*: 4x 2.5" SSD or 3x 2.5" SSD + 1x 3.5" HDD *ATX PSU Mode*: 2x 2.5" SSD

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Razer Opus X

Does half the price mean half as nice?

NOT LONG AGO, we had Razer's Opus headset in for review and we were impressed with the company's first attempt at breaking into the lifestyle audio market. The ANC headset was a premium pair for a first-time effort, but it did come with a hefty $200 price tag. For Razer's second release, the price has been slashed in half for this 'lite' version, making the new Razer Opus X potentially more inviting. So, what has been sacrificed to make this cut and is it a more sensible purchase?

There is one immediate change that you'll probably have noticed, a baby pink color scheme, though Razer calls it quartz. The other options are green, which is equally as bold, or they also come in mercury which is probably the most sensible selection. Although the original pair had a special BAPE edition, the only other color choice was black, so a bit of a change here. Other than the vibrant new colors, the new Opus X is not THX-certified, so it ditches the logo on the earcups. Also, the Razer logo itself is now the same color as the body, giving a more minimal look to the design.

Another change is what comes with the headsets. With the original pair, you got a carrying case, 3.5mm cable, USB-A to USB-C cable, and an airplane headphone adapter. With the Opus X, you don't get the carrying case, 3.5mm cable, or the airplane adapter. This headset ditches the analog connectivity and is Bluetooth only, so no need for the excess cables here. Of course, the more connectivity options the better, but we have to keep the price tag in mind.

A few things remain from the original Opus, including the solid build quality and layout. The right earcup has all the functionality, featuring the power button, indicator light, volume up and down buttons, and a playback button. The power button doubles as an active noise-cancellation cycle button to choose different levels of ANC.

It still features a gaming mode, but now with a lower latency speed of 60ms. In day-to-day life, this will be a more appropriate feature to use when watching movies than gaming. Although you could use the Opus X for gaming, a regular headset with a designated gaming mic would be more appropriate. The mic on the headphones is usable for phone calls or mobile gaming, but it isn't the clearest or most polished. If you need to go down the gaming route, Razer certainly has better-focused headsets in its lineup.

We found the original pair were comfortable but these are even better. The cushions in the earcups are slightly plusher and although they weigh the same, the Opus X feels a little lighter on the head. That means they are great for long usage, just what you'd hope for with a lifestyle pair of headphones.

Although the headphones are no longer THX-certified, there is little noticeable difference in sound quality between the new and old pairs. Considering the big price cut, this is a great advantage for the Opus X. The cans produce a similarly rich and balanced sound with plenty of clarity in the high-end. The difference is that the bass seems to be a little stronger. At times, it is a little overwhelming, but for more EDM-style music it can certainly pump out some surprising power.

Combined with an ANC function that carries over from the originals, this pair of headphones is a great addition to your day-to-day life. It does a great job of blocking out background noise, keeping you focused and immersed in your own world. We can't ignore the price and in this case, it's very good for this particular version, but that makes it harder to justify the original more expensive pair. The price cut doesn't sacrifice the battery either with an impressive run time of up to 30 hours with ANC and up to a whopping 40 hours without it.

We'd recommend the more subtle white/silver 'mercury' model, but if you don't care about that, you will be more than delighted with the new bold pink and green options Razer offers. Ultimately, if you are after a high-end-sounding pair of lifestyle headphones with a cheaper price tag and can settle for the single Bluetooth connectivity, the Opus X offers great bang for your buck. **–SAM LEWIS**

VERDICT
8

Razer Opus X Headset

⊞ **GREAT VALUE** Great comfort; solid battery life; crisp clear sound; immersive ANC.

⊟ **SO NEAR** Only one form of connectivity; slightly overwhelming bass; average microphone.

$99.99, www.razer.com

SPECIFICATIONS

Driver Type	40mm dynamic driver
Frequency Response	20Hz-20,000Hz
Connectivity	Bluetooth 5.0
Design Style	Closed back
Weight	0.59 lbs

Logitech StreamCam

The simple webcam solution?

MORE AND MORE features are being added to webcams these days. On the one hand, this is great to see, yet it throws these machines' simplicity straight out of the window. Sometimes, all you need is a small, easy-to-use webcam that delivers a high-quality image you can take with you on your travels. The StreamCam by Logitech claims to be a premium webcam for Full HD streaming and content creation. So does it meet these expectations and should you be adding this peripheral to your setup?

Logitech's contender takes the crown for the smallest of the bunch of our recent cam reviews, although it's a little on the chunky side. With its lightweight form, it's ideal for either a more minimal setup or one where portability is key. This may give the illusion that the StreamCam is potentially cheap, but that's far from the truth. At first glance, it's a quirky little thing that feels well put together. The graphite model we have for review is a little more subtle than the white variant and the grey mesh fabric surrounding the lens at the front suits it better. And yes, you did read that correctly—grey fabric on a webcam. It's a bit random, but we love it. Hidden in the mesh are a white live indicator and the camera's microphone.

It comes with a tripod mount, always handy, and a monitor mount which is also just as durable made out of the same thick plastic that coats the camera. With plenty of angle adjustment and a soft rubber grip, it's easy to get it hooked up to your monitor. The webcam also has an unusual quirk in that you can rotate the camera to a portrait position. It sounds interesting at first but is probably quite a pointless feature. If you are generally going to film in a portrait format, you'd just use your phone. Annoyingly, the 'Logi' logo is designed to suit the camera better in this orientation and is to the right of the lens when using the webcam in the more normal landscape mode.

So, with the form of the camera living up to the premium characteristics, what about the rest of it? Setup, like most webcams, is quick and easy. Instead of a type-A cable, it has a type-C, which is great for newer devices, but not so good for older ones. It isn't detachable, which could also be an issue if it gets damaged.

The camera can be controlled using the companion app, called Logitech Capture, which can adjust the image. After downloading the app, we get a first look at what the StreamCam's quality is like—and it's pretty clear. The room in which we tested the camera isn't the brightest and yet the image quality looks pretty good out of the box. With this promising start, it's time to play around with some of the settings. The app is fairly well laid out with the preview window in the center and the settings on the left-hand side panel. A good point here is that the settings are saved onto the camera and will be carried over to other uses, such as a Google Meet call.

We change the resolution to Full HD, as it can shoot in 1080p, and also upped the frame rate to 60fps to test out the StreamCam's full potential. As we were in a fairly dim environment, we made use of the backlight correction feature, which works well to give some detail to the background. The brightness, sharpness, highlights, and saturation can also be adjusted, but the out-of-the-box look was just about what we were hoping for.

It has a 78° field of view, which gets your room in the shot but often means you may have to zoom in. Although it does have an auto framing feature, it would be nice to see an optical zoom on this webcam as its target audience is supposedly streamers (the clue is in the name). Also, most streamers won't be using the built-in microphone and that's kind of for the best. On playback, it sounds a little tinny and flat, so your best bet is to use one on a headset or a standalone mic.

It's a good camera, and you can use it for streaming as the quality and frame rates should certainly satisfy. However, calling it the 'StreamCam' is a little misleading as there is nothing specifically aimed toward streamers. If it contained a backlight or had optical zoom, these features would appeal more to the streaming community than the built-in microphone or portrait mode will do. If you are looking for a well-designed and easy-to-use daily camera, then this is a good bet, albeit not the cheapest option out there. **–SAM LEWIS**

VERDICT
7

Logitech StreamCam

⊞ **BOXES TICKED** 60 fps; clear Full HD; decent accompanying software.

⊟ **WRONG TARGET MARKET** No optical zoom; no privacy shutter; flat microphone; a few unnecessary features; price.

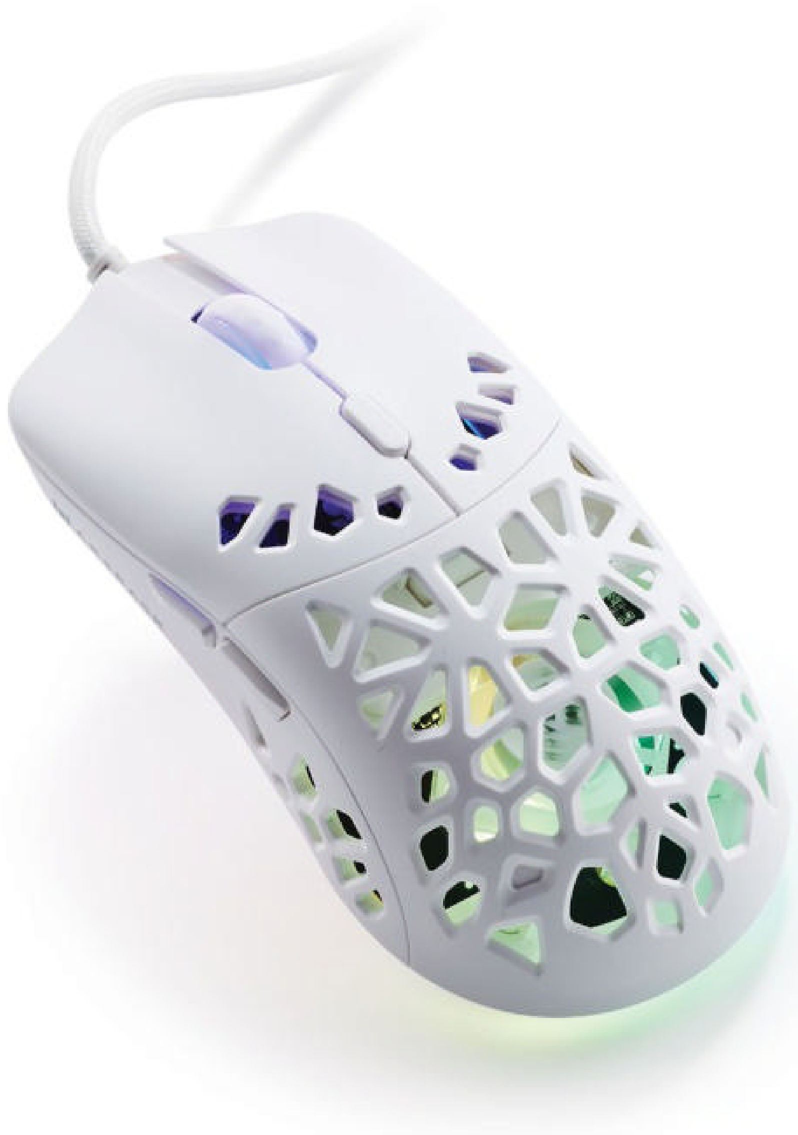
$169.99, www.logitech.com

SPECIFICATIONS

Video resolution	1080p, 720p or 360p @ 60/50/30/25/24 fps
Lens	Premium Full HD Glass lens
Aperture	f/2.0 – focal length 3.7 mm
Field of view	78°
Focus type	Auto
Connectivity	USB 3.1 Type-C
Weight	0.48lbs

Marsback Zephyr Pro

I'm your smallest fan



IT'S FAIR TO SAY that 'it's a mouse with a little fan inside it' was a statement met with some derision by the *Maximum PC* team. 'It keeps your hand cool!' this reviewer cried, to be met with the Slack chat equivalent of raucous laughter. There were many doubts that the Zephyr Pro (from industry fresh-faces Marsback, who previously released the lower-spec original Zephyr) would be anything more than a forgettable gimmick product.

And yet, as we used the Zephyr Pro, we found it to be a surprisingly competent gaming mouse. Not satisfied with merely being functional, its core gimmick actually does work. The tiny fan housed inside the Zephyr Pro's honeycomb casing is near-silent and generates no discernible vibration; both major factors in the criticism of the first Zephyr. The plastic exterior remains cool even under the sweatiest palm, but the breeze generated by the fan is gentle enough so as not to distract during use.

Priced at $59, the Zephyr Pro just about falls into budget territory for a gaming mouse but offers solid performance nonetheless. A 16,000 CPI PixArt sensor ensures good sensitivity for twitchy gaming moments, while wide PTFE feet and a woven paracord cable ensure that this mouse can glide comfortably over any desk surface. It has reliable Omron switches underneath the buttons too, rated for up to 50 million clicks.

In terms of buttons, the Zephyr Pro has a fairly pedestrian layout. In addition to the left and right mouse buttons and a satisfyingly sturdy scroll wheel, there are two thumb buttons (no southpaw support here, sorry lefties) and a DPI button in the center. There are also two buttons on the underside; one for switching between RGB setups and one for turning the fan on and off. You can't adjust the fan speed, which is a strange omission, but even at full speed the fan isn't noisy, so it's something of a non-issue.

It's a fairly minimalist selection of buttons for a gaming mouse and that could be a problem for some serious PC gamers. MMORPGs and MOBAs typically demand a greater selection of mappable buttons for optimum engagement, and some shooter fans will mourn the lack of a sniper button. This comes down to personal preference though; if you like a simple layout, it's not a problem.

The Zephyr Pro is an impressively lightweight mouse, weighing in at a mere 2.4oz (69g). It's not hard to understand why; the perforated exterior lays bare the guts of the mouse, which essentially equates to a fan, some switches, and a basic strip of PCB. The weight distribution isn't the finest we've seen, with the front of the mouse being a bit heavier than the rear, which may result in some uneven handling for fingertip-grip users.

While the overall construction quality doesn't quite measure up to some more established manufacturers (the side buttons feel a little spongier than similar budget offerings from, say, HyperX), it's certainly not bad. The customizable RGB lighting makes for a distinctive appearance when combined with the symmetrical honeycomb design. A thin strip of RGB runs around the base of the mouse, while the translucent fan housing itself is lit from below and the scroll wheel changes color to denote the current DPI setting.

Speaking of RGB, Marsback has a decent piece of utility software for customizing your Zephyr Pro. It's nothing too fancy, but it has all the usual tricks—RGB editing, DPI modes, on-board memory for saving your profiles—and is actually pretty easy to use compared with the programs available from certain big-name manufacturers.

Considering that the original Zephyr was written off by many reviewers as a novelty, the Zephyr Pro is a triumphant round two for Marsback. If clammy hands on hot days (or in particularly spicy *Valorant* matches) are the bane of your existence, look no further: Marsback has got your back. **–CHRISTIAN GUYTON**

VERDICT

8

Marsback Zephyr Pro

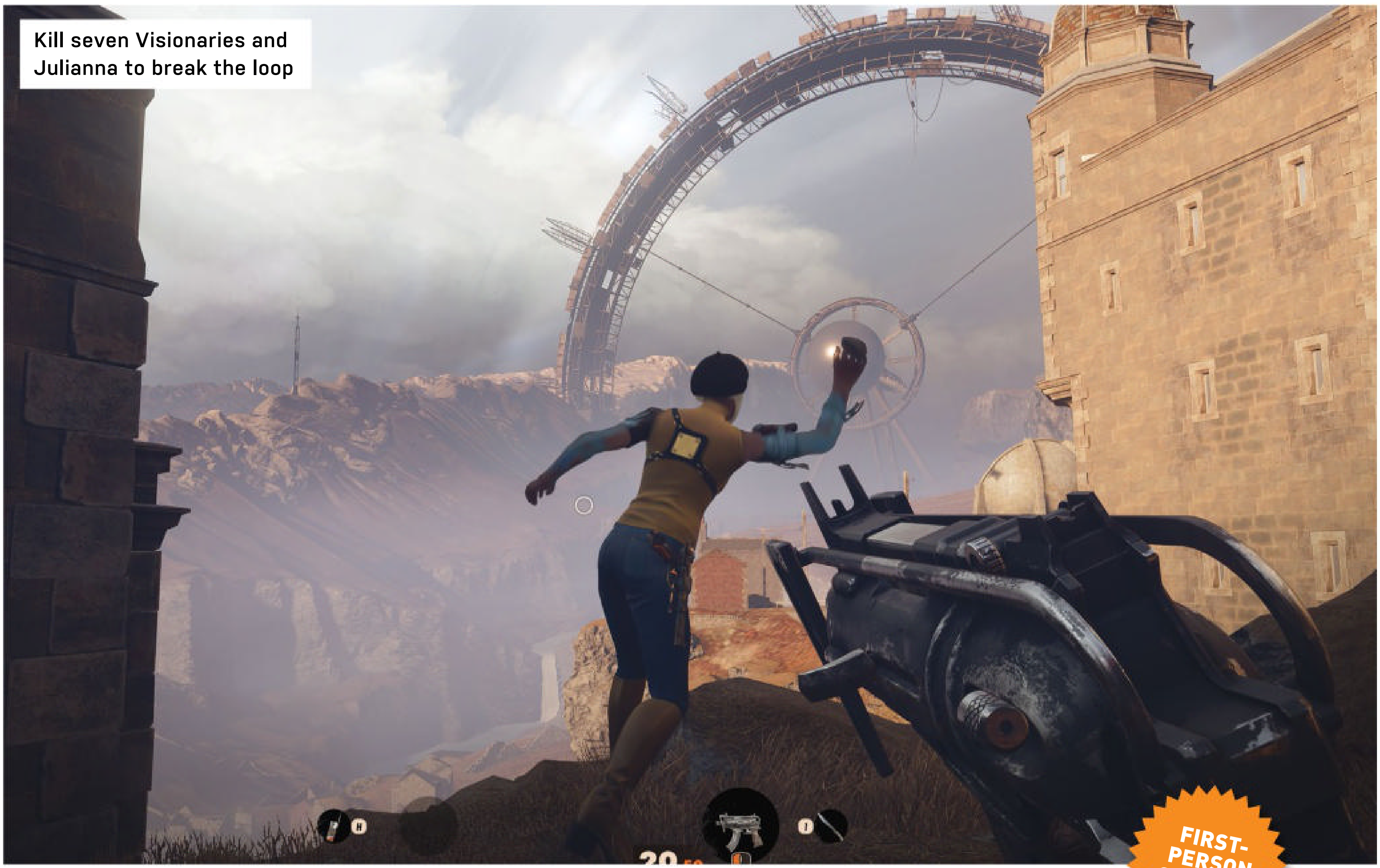
⊞ **COOL** Effective but affordable; aesthetically striking; very lightweight; gimmick actually works.

⊟ **CLAMMY** Not the most ergonomic; few buttons for a gaming mouse.

$59, marsback.com

SPECIFICATIONS

Sensor	PixArt 3389
Sensitivity	16,000 CPI
Speed	400 IPS
Polling Rate	1000Hz
Programmable Buttons	6
LEDs	3x RGB zones
Cable Length	6 Ft
Weight	2.4oz (without cable)



Kill seven Visionaries and Julianna to break the loop

FIRST-PERSON SHOOTER

Deathloop

Repetition dissected, perfected, then done all over again

TIME FLIES like an arrow. Fruit flies like a banana. And in *Deathloop*, time goes around and around and around. Unless that is, you can escape it.

That's the basic premise of Arkane's game—to escape the time loop. Violently. You wake up every morning on a beach outside a facility that has been locked inside a time loop by AEON, a hedonistic organization one step outside a Bond movie that's found a way to make sure the party never, ever stops. As a result, the island exists in a time loop.

IT'S PARTY TIME, AGAIN...

Whatever happens, no matter how hard you party or even if you jump off a wolf's head statue into the icy sea below, you'll wake up in the morning in the same place you always do, ready to start all over again. In your character Colt's case, that's on a beach near an outlet from tunnels that run under the island. From here, he can gain access to anywhere in the facility, popping up to follow leads, track down items, and kill, kill, and kill again.

In order to escape or break the loop, Colt must take out the eight 'Visionaries' who run the facility. That's not going to be easy, as not only are they armed and protected, but each of them carries a 'slab' that gives them powers that are surprisingly familiar if you've played Arkane's previous titles: the *Dishonored* games and *Prey*.

Kill the visionaries, get their powers, find a way to make them persist when the loop resets, and you're on your way to killing all eight in one go. Colt has his own slab, which gives him the ability to come back from the dead twice before the loop resets—effectively, three lives. Others permit invisibility or short teleportation hops, *Dishonored*'s Domino is reborn as Nexus, while Havoc makes you stronger and tougher. You can only equip a few guns and powers at once, so working on a favored loadout is key.

Each day is split into sections, and certain Visionaries are only vulnerable at particular times. If you die, or time on the island reaches midnight, everything resets and you wake up on the beach again. Thus, through trial and error, exploration and killing, you work out a plan to eventually take out seven of the Visionaries in one graceful run. Each one killed provides you with a substance that allows you to retain your equipment through resets, cutting down on the amount of repetition you need to do. Each loop gives you more knowledge and better equipment.

VISIONARY APPROACH

The eighth Visionary, Julianna, is different. Not only does she reside on a part of the island you can only reach in a particular way, but she will actively hunt you down. At the beginning of every loop, she announces to the island's population that you have betrayed them, and everyone tools up and goes out to watch for you.

That would be bad enough if all you had to worry about was the clockwork AI, but Julianna can be controlled by another player, invading your game with the sole job of taking you out (there are limitations in place to prevent high-level players from repeatedly ruining newbies' games).

Julianna's slab allows her to take the form of any other character, so when an otherwise innocuous NPC starts coming right for you, you'll know it's a

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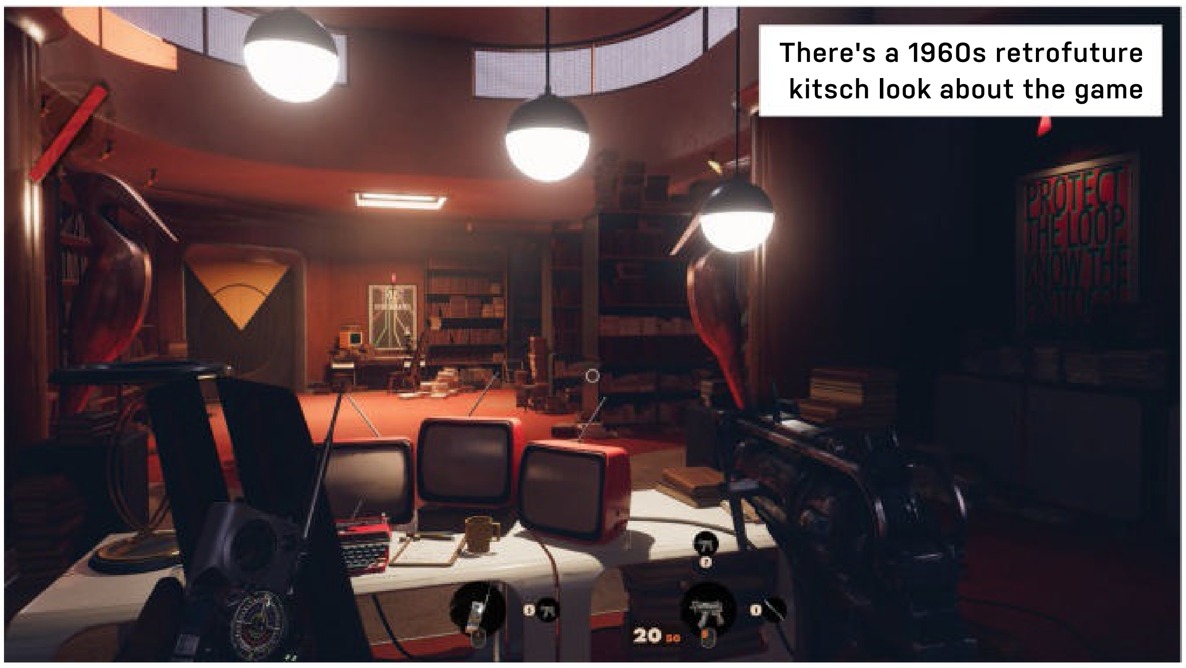
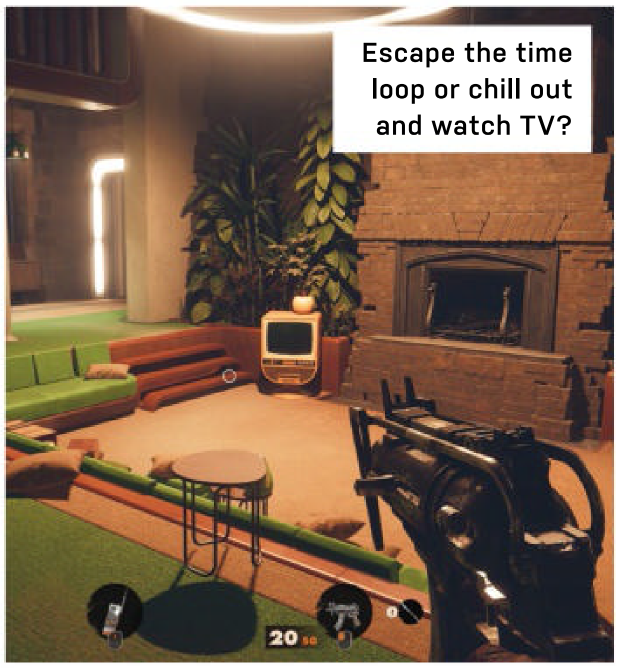
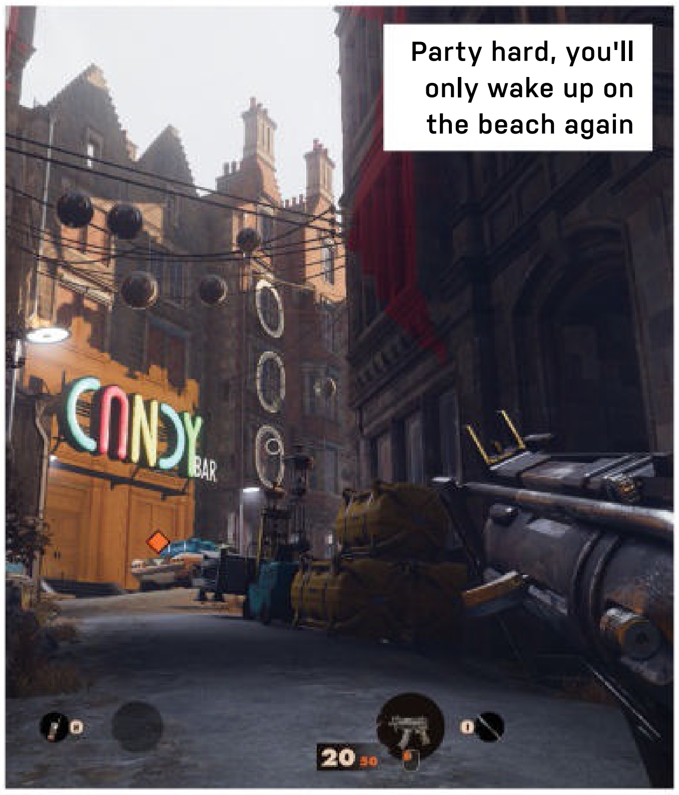
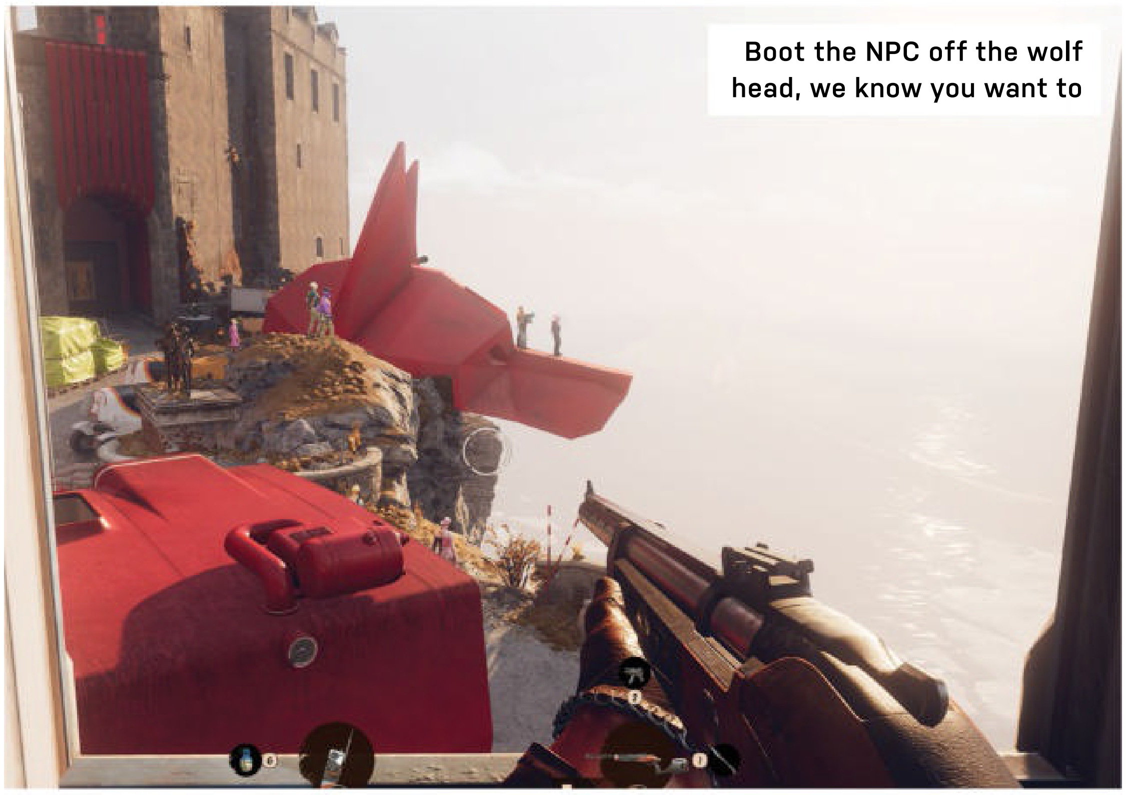

There's a 1960s retrofuture kitsch look about the game


Escape the time loop or chill out and watch TV?


Party hard, you'll only wake up on the beach again


Boot the NPC off the wolf head, we know you want to

real human behind the hail of gunfire. This one-on-one multiplayer component can be switched off, meaning your now single encounter with Julianna ends up in a gunfight as the AI lacks the spontaneity of a human invader. She's tough, but also only has one life, meaning Colt is favored in their game of cat and mouse.

ON THE EDGE

The decision for *Deathloop* not to feature non-lethal takedowns is an interesting one. Bodies dissolve once you've finished killing them, so there's no need to hide them in bins or vegetation. You carry a machete, which can be used for silent kills, there's a silent projectile weapon useful for headshots, and a combination of your strong right boot and NPCs' tendency to stand on the edge of cliffs and buildings leads to some comic moments.

But it's kill, kill, kill, all the time. No Clean Hands achievement here, even though the game seems to want you to play it stealthily. However, it's the kind of stealth that purely acts as a precursor to extremely loud chaos, just as it did in the rebooted *Wolfenstein* games. Sure enough, the idea for *Deathloop* dates back to Arkane's work with MachineGames on *Wolfenstein: Youngblood*.

The world doesn't react to your actions in the same way *Dishonored*'s did, and there are no quicksaves—no saves of any kind unless you have just completed a time section and advanced to the next—so you won't be inching your way along the rooftops with your finger stabbing F9 each time you get past another guard. But *Deathloop* is not *Dishonored*, it's much more of a playground, the knowledge that if you die you'll just wake up on that beach again bringing gratification in the destruction just as the NPCs shoot themselves out of giant cannons for fun.

If there's a downside to all this, it's that there's a lot going on in *Deathloop* and the game needs to explain it all to you. Tutorials and popups sometimes feel like they're never going to end. But this is the tiniest of complaints about a towering achievement. Arkane has built wheels within wheels, then stuck it all inside the biggest wheel of all.

From its retrofuturistic 60s/70s kitsch aesthetic to the way you eventually learn to use the looping nature of the game to your advantage, *Deathloop* may be an open-world shooter, but it feels like something excitingly new. **–IAN EVENDEN**

VERDICT 9

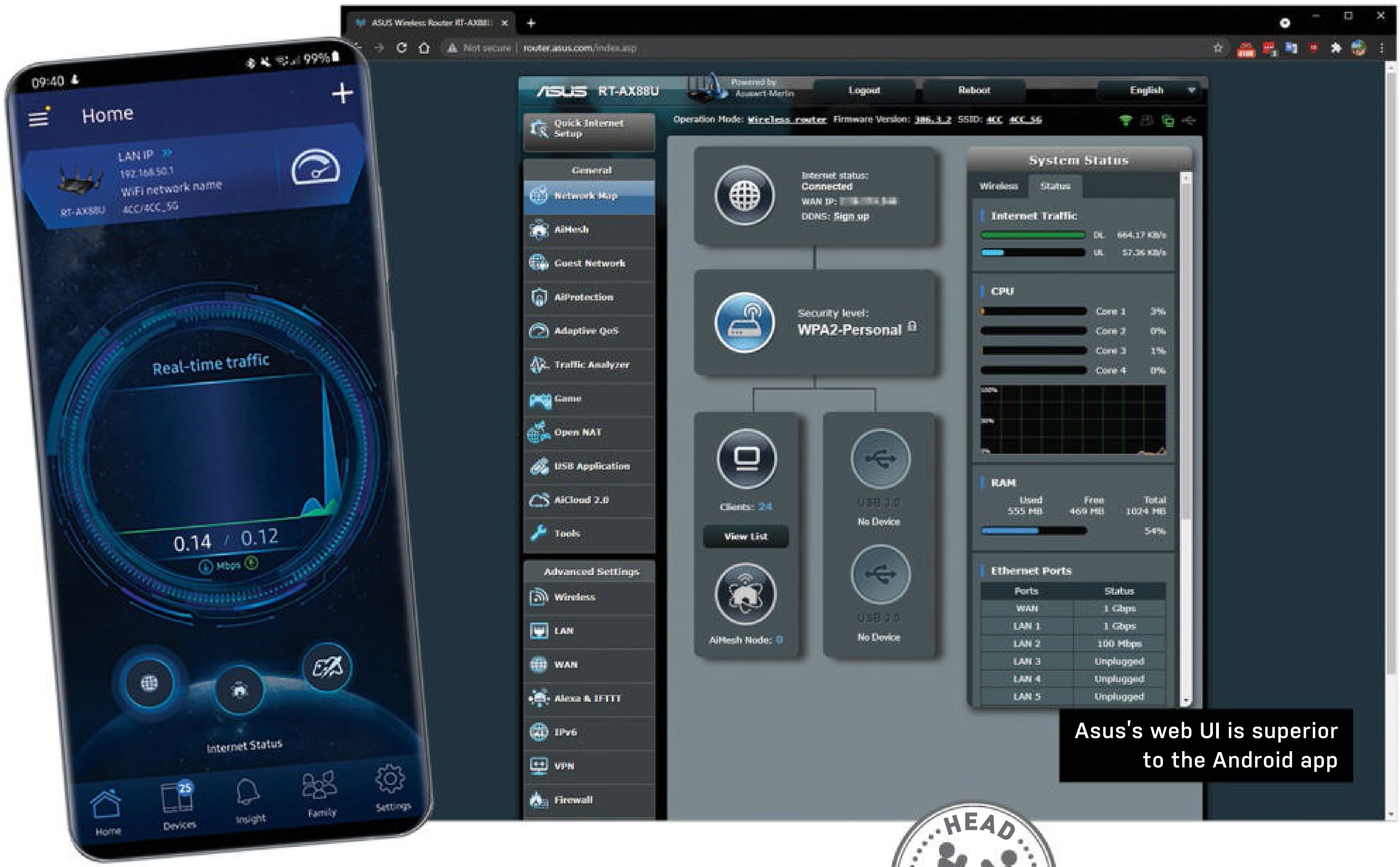
Deathloop

LOOPING Ridiculously clever game with great looks.

DROOPING Has to spend a lot of time explaining itself.

RECOMMENDED SPECS CPU, i7-9700K / Ryzen 7 2700X. RAM, 16GB. GPU, RTX 2060 (6GB) / RX 5700 (8GB).

$60, bethesda.net/en/game/deathloop, M-rated


09:40
99%
Home
LAN IP
192.168.50.1
WiFi network name
RT-AX88U
4CC/4CC_5G
Real-time traffic
0.14 / 0.12
Mbps
Internet Status
Home
Devices
Insight
Family
Settings
ASUS Wireless Router RT-AX88U
router.asus.com/index.asp
RT-AX88U
Logout
Reboot
English
Quick Internet Setup
General
Network Map
AiMesh
Guest Network
AiProtection
Adaptive QoS
Traffic Analyzer
Game
Open NAT
USB Application
AiCloud 2.0
Tools
Advanced Settings
Wireless
LAN
WAN
Alexa & IFTTT
IPv6
VPN
Firewall
System Status
Wireless
Status
Internet Traffic
CPU
RAM
Ethernet Ports
View List
USB 3.0
No Device

Operation Mode: Wireless router Firmware Version: 386.3_2 SSID: 4CC 4CC_5G

Internet status: Connected
DDNS: Sign up

Security level: WPA2-Personal

Clients: 24

AiMesh Node: 0

DL 664.17 KB/s
UL 57.36 KB/s

Core 1 3%
Core 2 0%
Core 3 1%
Core 4 0%

Used	Free	Total
555 MB	469 MB	1024 MB

54%

Ports	Status
WAN	1 Gbps
LAN 1	1 Gbps
LAN 2	100 Mbps
LAN 3	Unplugged
LAN 4	Unplugged
LAN 5	Unplugged

Asus's web UI is superior to the Android app

Asuswrt Merlin vs Netgear Nighthawk

The Battle of the router interfaces

ROUTERS HAVE COME a long way in the past 20 years, each year brings better features, new designs, and bigger wireless ranges. But for the enthusiast, a good router stretches beyond just "how quick is it?" And quickly moves on to "how easy is it to configure?" Today, we're pitting two behemoths against each other. Netgear vs Asus, US vs Taiwan, in a battle of the networking giants. Which router's onboard UI comes out on top? What features do you get? And which is easier to set up?

But there's a twist. Instead of running on the stock Asus firmware, we'll be comparing the third-party Asuswrt-Merlin variant instead. Identical in almost every way to the stock config, the Merlin features an expanded feature list, while retaining the look, feel, and features of the default UI. With support for third-party software, performance optimizations, to VPN solutions, bug fixes, DNS-based filtering, and a host more additions. In fact, Asuswrt-Merlin's firmware has been so impressive over the years, Asus has included features from it in its own stock configuration.

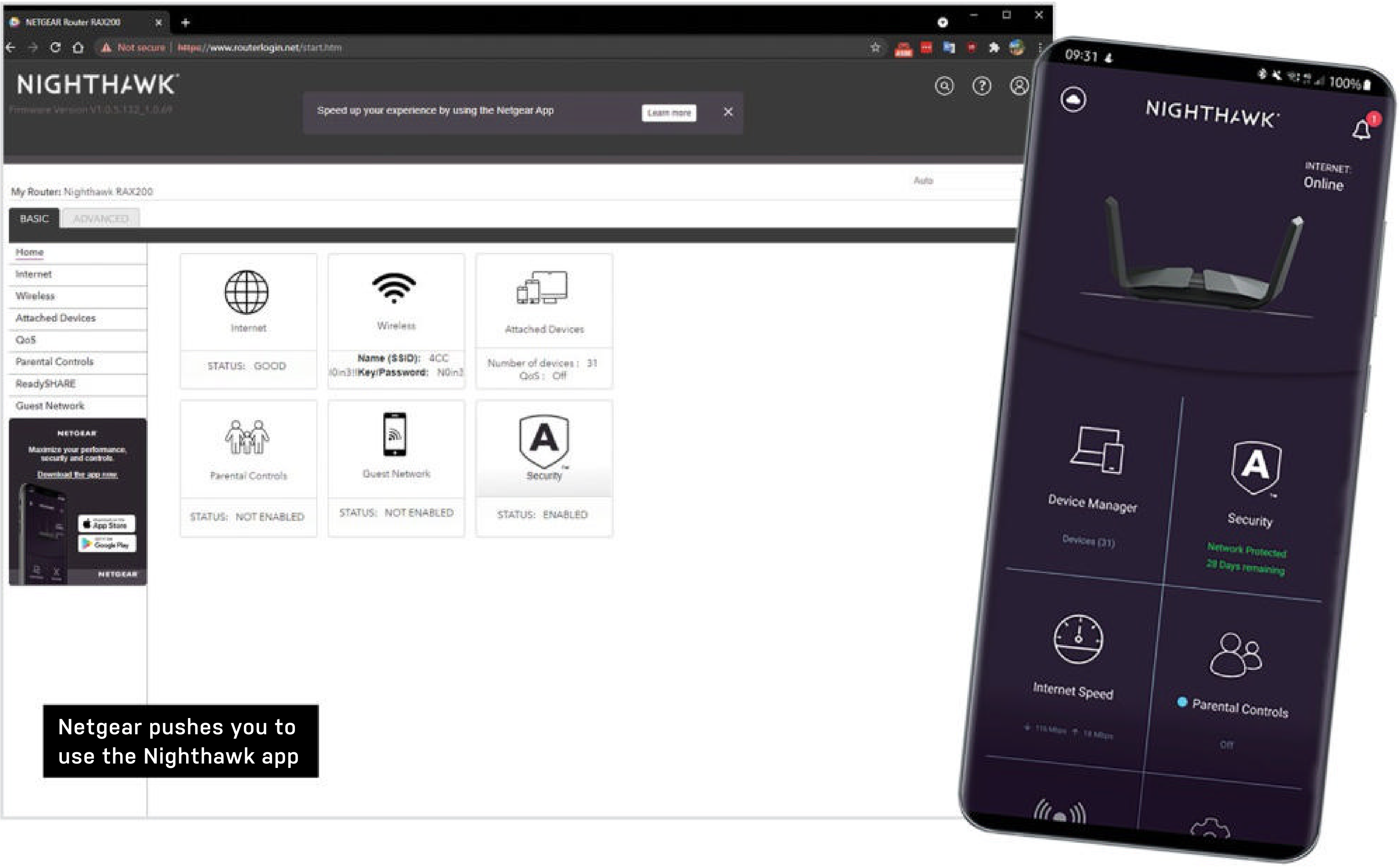
The initial setup for Asus routers is fairly seamless. Plug in direct from the modem, let the device power on, then connect either via Ethernet, LAN, or Wi-Fi. Then, head to a web browser and type in router.asus.com and it takes you straight to the main router admin page. Enter the username and password, and you're in. Depending on your ISP, you can then head to WAN settings, and input your user and password for PPPoE, or leave it blank if you're running DHCP instead.

For Netgear, it's more complicated. The same basic premise applies, plug in the router, connect the modem, power it up. Once that's done, however, you can't just connect and log in using an admin and password. Instead, you're encouraged to scan the QR code provided with your phone, at which point, you'll be prompted to download the Nighthawk mobile app.

This will then identify your router's Wi-Fi network, and run you through the setup procedure that way. The process involves turning the modem and then router off and on, then add a username and password if you require a PPPoE setup (inputting long usernames by phone isn't fun). However, the phone also provides an uncontrollable variable. Take the Samsung S21 Ultra, if it can't detect an internet connection, it disconnects from Wi-Fi and uses mobile data instead. If it does this during setup, it can crash the entire thing, meaning you have to start again. It took three attempts to get past the initial setup and required us to disable mobile data to get it right. Once set up, you can log in via routerlogin.net, which gives you access to a comparatively rudimentary UI, with numerous adverts and pop-ups pointing to the app.

Netgear's basic web UI is practical, although not flashy. On arrival, it gives you a quick update on attached devices, internet status, Wi-Fi and Guest Network status, and whether your Armor security package is enabled. The basic page has a number of tabs, including Internet (access to your login and password, WAN preference, MAC and DNS settings), Wireless (where you can control WiFi AX, SSID broadcast, channel config, security), QoS (providing

© ASUS, SAMSUNG


NIGHTHAWK
Speed up your experience by using the Netgear App
Learn more
My Router: Nighthawk RAX200
BASIC
ADVANCED
Home
Internet
Wireless
Attached Devices
QoS
Parental Controls
ReadySHARE
Guest Network
Internet
STATUS: GOOD
Wireless
Attached Devices
Parental Controls
STATUS: NOT ENABLED
Guest Network
STATUS: NOT ENABLED
Security
STATUS: ENABLED
09:31
100%
NIGHTHAWK
INTERNET: Online
Device Manager
Devices (31)
Security
Network Protected
28 Days remaining
Internet Speed
Parental Controls
Off

Netgear pushes you to use the Nighthawk app

some basic bandwidth allocation settings, backed up by online profiles, there's also a speed test function here), Parental Controls (for internet usage controls, time limits on apps/websites, age-appropriate filters and more), ReadySHARE (where you control your attached USB storage), Guest Network, and, last but not least, Attached Devices, which is genuinely awesome.

Asuswrt has this too, but not to the same caliber. Netgear actively identifies what each item connected to the network is using an online database, providing it with a visual indicative icon, a product name, and assigns it a bandwidth priority. It also informs you of the connection type and local IP address. There's also a handy link taking you to "Access Control", where you can block devices. Asus has something similar, but it's far more simplified. If you want to input the product name, you can, but you have to do it yourself. There are icons but it's not often accurate. You can however sort by connection type, a feature that's sorely missed on the Netgear setup.

Moving across to the advanced setup tab takes this all a step further, and gives you more in-depth features, port-blocking, Traffic Meter, Port Aggregation, Static Routes, Dynamic DNS, and a whole host of logs and other good stuff.

With Asus, it's a lot more clean-cut, you get a far better visualization on first entry into the web GUI, with internet status, WAN IP, DDNS signup, internet traffic figures, and CPU and RAM utilization charts too. You can also see what speeds are capable on each device plugged into each ethernet port, and more. On first appearances, it's a superior UI. Everything is neatly aligned in tabs on the left of the page, including features such as Guest Networks, AIProtection, Adaptive QoS, Traffic Analyzer, Game mode, Open NAT, and the VPN, IPv6, Firewall settings, and more. At first glance, it's far easier to navigate around than Netgear's solution.

Both solutions have a form of security on board. Asus's is discreet, sitting solely on the router, it blocks access to malicious websites, and attempts, and gives you a device-by-device breakdown on how many attacks it has blocked. Armor, Netgear's proprietary software package partnered with Bitdefender, is more involved, again requiring the app. It informs you when a new device has connected to the Wi-Fi and then scans it for vulnerabilities. It also analyzes your Wi-Fi network for security flaws and, like Asus's AiProtection, blocks malicious attacks.

It comes with Bitdefender Security for all your devices, and a limited 200MB a day Bitdefender VPN. But this is a subscription package that will set you back $70 a year without discount (currently 35%), or you can upgrade for an extra $40 for unlimited VPN data. Of course, all of those features are buried in the app. Would Netgear consider dropping Bitdefender and including Armor for free or at a discounted price? Sadly not. It's an awesome piece of software, but it comes at a cost when you have paid $400+ for a router that supports it. As an enthusiast who likes to pick their antivirus and VPN solutions, we are unlikely to renew, despite these extra features.

Ultimately, both are similar, but with two different approaches to how you use them. Both have a solid web UI, with Asus eking out a win on usability and security features, and both have mobile apps with Netgear's far superior in function and form. However, Asus slightly tops the competition, mainly because AiProtection is included as standard with the router, unlike Netgear's Armor equivalent. **–ZAK STOREY**

VERDICT 9 KICK ASS!

Asuswrt Merlin v386.3_2

➕ **GANDALF** Exceptional web interface; easy to navigate around; simple setup; vast featureset; Ai Protection is good, and also free.

➖ **VOLDEMORT** Phone app hard to navigate.

$free, www.asuswrt-merlin.net/

VERDICT 9

Netgear Nighthawk v1.0.5.132_1.0.69

➕ **FERRUGINOUS HAWK** Solid web interface; impressive device detection; epic security solutions; incredible app.

➖ **SPARROWHAWK** Setup can be infuriating; security bundle is pricey.

$free, https://www.netgear.com/

© NETGEAR, SAMSUNG

LETTERS

WE TACKLE TOUGH READER QUESTIONS ON...

> Future Features
> CPI Mice
> Too Many Words!

All the words!

Hi Zak, I'm really enjoying the mag this year, especially Ian Evenden's features, which are epic, but I do have a question for you specifically. Why do you write so much? Don't get me wrong, I enjoy your work, but maybe you should let some of your other team members write more often? Since you joined your name has been all over the mag. Keep your feet on the ground, yeah?

Otherwise, keep up the good work. **–Keiran R.**

EDITOR-IN-CHIEF, ZAK STOREY, RESPONDS: Ahh yeah, it has been a tricky time ever since I re-joined *Maximum PC*. For those who don't know, I became editor two days before we went into lockdown back in March 2020, and since then, a number of setbacks have really put a dampener on my plans for the mag and forced me to perhaps write more than I should.

You're absolutely right, as far as editors go, I actually write way too much. Don't get me wrong, most editors generally contribute around six to 10 pages a month, but there have been issues of *Maximum PC* where I've had my name attached to two or three times that number, and been involved with a lot more content on the side of that as well. However, I absolutely love writing, it's a big part of the job, and a pleasure to do. When I took over from Alan, I knew I was going to be a much more "hands-on editor" (his words), as I'm also big into system building, which is one of the staple features we have in *Maximum PC*.

When I first joined, Future took some drastic measures, in anticipation of the effects that COVID might have on the market. You may remember that we lost 12 pages of editorial content from each issue, and a huge chunk of our budget too—I won't lie, it was a pretty rough time. From March to October, we were down considerably, and even with a reduction in pages (originally designed to stave off print costs), it was a challenging period that required me to cover more areas.

Then, we had a bit of trouble in the team in August, and one of our regular writers had to take some time out due to stress and life circumstances, so I had to cover those pages too. By November, Christian was sadly diagnosed with cancer and went into chemotherapy immediately.

It wasn't until January that we got Sam on board, and, of course, it took a couple of months to get him up to speed with everything that's going on. There was some good news in that Christian rejoined the team full-time in early May, at which point, I was in a unique position of having two staff writers. That meant I could step back a bit and work on planning future content, and revamping the mag.

However, sadly, Christian has recently had to go back into chemotherapy (although on a reduced dosage, thankfully). He has a month out in November, so it looks like my face will be sticking around for some time to come. Sorry!

These aren't excuses, it's just been a rough couple of years for us as a team, and very much why I've written as much as I have here. Trust me, once things get back to normal, I'll happily step back a bit, and focus on the bigger goals, namely getting online again, rebuilding our website, setting up the plans for our regular YouTube content, creating the weekly *Minimum BS* podcasts, and of course, all the other stuff buried deep in the back of my brain. This is, after all, *Maximum PC*, not Maximum Zak!

Event on the Horizon

I have enjoyed the magazine for many years, but Ian Evenden's article on how solar flares could wipe out all our technology in one go was phenomenal. Ian certainly did a great job, and the article was so engrossing you had to keep reading right to the end...

–R. Linder

EDITOR-IN-CHIEF, ZAK STOREY, RESPONDS: Glad you enjoyed it, I forwarded your message on to Ian, and I think you made his day. Yeah, the whole concept of a solar storm and the Carrington Event is just fascinating. I'm hoping next year we can take another look at that,

↘ submit your questions to: editor@maximumpc.com and the mitigations that are being put in place to protect our much-loved tech. I know some folk might find that a bit sensationalist, given how much we focused on it as a sort of "apocalypse we can't avoid" scenario, but there just wasn't enough time (or pages) to give it the full treatment we wanted to.

Ian's great at these kinds of features, and I've championed his work for some time. We're working on a couple of feature ideas for the next few issues as well that you might enjoy. We're looking at weather prediction and supercomputers (holiday edition), how it works, what the industry looks like, and we're also hoping to create an epic feature that I've affectionately dubbed "the internet" for our March edition. Ian's promised me some incredible interviews for that one. I can't say much right now on who he's interviewing, but I'm super-excited about it.

For those who prefer software, rather than the historical side of things, I've also recruited Nick Peers to provide some more incredible features as well over the coming months. He will be giving us a full guide to router settings, an in-depth look at data recovery, and a handbook on "how to save Windows" from common problems and bugs and such over the coming months. Of course, we have some of our regular annual favorites, including Gear of the Year and Geek Quiz coming up as well. Lots of Holiday goodies.

It's going to be a busy few months for myself and the team here (our deadlines up to the winter period always get a bit crazy!) but once it's all wrapped up, there should be some awesome issues for you all! I do hope you enjoy them!

Crazy CPI Mice!

Hi all, why are there so many mice out there with crazy DPI ratings? Like who uses a mouse at 26,000 DPI? That's just crazy! I barely have mine above 1,000, and the pros I follow don't even go that high. Can you explain why this is?

–G. Ford

EDITOR-IN-CHIEF, ZAK STOREY, RESPONDS: It's a marketing ploy more than anything, to understand it helps to know just how mice work. First up, DPI is an incorrect term for mice but is used because it's known by the public. DPI refers to dots-per-inch. In the world of print, that tells your printer how many dots of color to print per inch of paper. Thing is, mice don't work that way, nor do their sensors.

With proper hardware manufacturers, you'll see the figure touted as "CPI" or "counts-per-inch", this is the number of times the mouse sensor detects the surface (or takes a count) when moved by one inch. There are a few other important numbers too: IPS (or inches per second), tells us how fast the mouse can move before it becomes inaccurate (a mouse with an IPS rating of 450 can travel at 450 inches per second, or 25.56mph). Also, the G rating tells you how much inertia the mouse can handle before the sensor can no longer accurately track the surface.

The reason why mice have such high CPIs these days is actually far more complex than you'd think. There are two main explanations, the first is artificial inflation (fortunately quite rare these days), and the second is to do with camera smoothing. There's a big difference between sensor-based CPI and firmware-inflated CPI. When we review mice here at *Maximum PC*, what we're looking for is perfect, unadjusted 1:1 tracking with the sensor and nothing else.

Some manufacturers advertise their mice as hitting super-high CPI figures, despite the fact the sensor just isn't rated for that kind of tracking. Instead, firmware takes over and increases that figure using angle snapping, pointer acceleration, interpolation, and other tricks. This is a problem because you can end up with accuracy artifacts, jitter, or worse, impacting your gameplay. You never know for sure if you missed that headshot, or if the mouse did.

Now admittedly, most folk (myself included) don't use mice above 3,000 CPI, I actually sit at around 1,200 or so, and there are few sensors out there that can't track that fast these days. But some manufacturers introduce these 'features'.

A good place to start when looking at mice is to identify the sensor and google it. Most mice use either a PixArt sensor or a tweaked variant of that, which is top quality. However, if you want to find the best sensors, I recommend visiting the website https://sensor.fyi/ which has a list of flawless mice and sensors and goes into more detail about the things listed above.

The second reason high CPI mice can be a boon is down to how your mouse interacts with the game you're running. It's known as angular granularity, and how smooth the camera is in-game when performing a matrix shift (i.e. rotating your view). You have to bear in mind that although your mouse is counting on a 1:1 basis, in-game cameras don't operate on a count basis, but rather a degree basis. They also have their own software layer that interprets the mouse movement. This can usually be adjusted, so you can increase or decrease the mouse sensitivity.

Theoretically, you can increase your mouse's CPI at a hardware level, and decrease the game sensitivity, to provide you with a higher granularity (courser rotation), or do the reverse for a lower granularity (smoother rotation). This is a bit beyond my own personal knowledge, but wepc.com wrote a fantastic article that's well worth checking out here: https://www.wepc.com/tips/cpi-vs-dpi/

Windows Help & Advice

With Windows 11 coming out shortly, is there any chance of the *Windows Help and Advice* magazine returning? I was a subscriber (through the PocketMags app) and used it a lot learning Win10.

–D. Marshall

EDITOR-IN-CHIEF, ZAK STOREY, RESPONDS: That's a sore point within the Tech Specialist team at Future. My boss actually ran that magazine with the help of Ian Evenden and an army of freelancers here. Sadly, it was closed down at the start of the pandemic to reduce expenditure.

I forwarded this to Graham (my boss), and sadly it seems there is no chance the magazine will make a glorious return, despite the obvious business opportunity there. He suggests checking out *Computer Active* (another Future title), as it should cover it in considerable detail over the coming months. Of course, we'll have a few tutorials here and there, though we don't cover Windows in as much depth as those guys do (or did).

It's always a shame to see magazines close like that, especially when anniversaries arise, or events like this pop up.

THE BUILDS

THIS MONTH'S STREET PRICES...

BUDGET

FINALLY, CPU STOCKS HAVE reached a stable level. AMD's Ryzen 3 3100 has remained in the budget AMD build, and for good reason. Firstly, $200 is a reasonable price tag for this chip. Secondly, it's great for what we want. The 3100 8-thread CPU gives us a decent experience with the additionally boosted speeds we had over the Ryzen 3 1200 from two issues ago. For now, it can sit comfortably in this build. The motherboard remains the same. The addition of the Ryzen 3 3100 brings a few perks, one of which is PCIe 4.0. We upgraded last time to the MSI B550M Pro motherboard to speed up data transferring in our budget AMD build. Paired with the XPG Gammix S50 Lite we added last time, this will ensure ultra snappy speeds. This Gen4 M.2 SSD is one of the fastest we can find and it's good value too, although 500GB can be chewed up pretty quickly. You can pick up MSI's Gaming Radeon RX 6700 XT, but it's almost double the price of the Radeon RX 6700 XT that is still currently unavailable, so we can't recommend this alternative route.

Gigabyte's DS3H V2 availability is unchanged so the ASRock B460M Steel Legend stays for our budget Intel build motherboard. We save a bit on the CPU, but nothing spectacular. The Core i3-10100 has fallen by $7, but we will take anything at this rate.

The 1TB Western Digital hard drives in both budget machines still cost $40. It's a brilliant budget storage solution and, unless a higher capacity drive sneaks into this price bracket, we can't see it going anywhere. The price doesn't differ for our SSD either, staying at a reasonable $54. We don't want to 'if it ain't broke don't fix it' for our budget builds, but the market for this sector hasn't opened up any more potential parts that can knock off what we already have.

Hopefully, with Alder Lake's release pending, we will see a fall in older Intel chips that can break into the budget category. GPUs are still scorching hot, price-wise. We won't be spending upwards of 200 percent RRP for some GPUs, especially not second-hand ones.

AMD INGREDIENTS

PART		PRICE	STREET PRICE
Case	Corsair 4000D Airflow	$95	
PSU	500W EVGA BA 80+ Bronze	$50	
Mobo	MSI B550M PRO AM4	$90	
CPU	AMD Ryzen 3 3100	$200	
GPU	AMD Radeon RX 6700 XT 12GB **NO STOCK**	$480	$840
RAM	16GB (2x 8GB) Crucial Ballistix @ 3200MHz	$75	
SSD	512GB XPG GAMMIX S50 Lite PCIe 4.0 M.2 SSD	$70	
HDD	1TB WD Blue 1TB 7200	$40	
OS	Windows 10 Home 64-bit OEM	$32	

Approximate Price: $1,132 or $1,492

INTEL INGREDIENTS

PART		PRICE	STREET PRICE
Case	Corsair 4000D Airflow	$95	
PSU	500W ARESGAME AVG500 80+ Bronze	$45	
Mobo	ASRock B460M Steel Legend **NEW**	$108	
CPU	Intel Core i3-10100	$160	
GPU	Nvidia GeForce RTX 3060 12GB **NO STOCK**	$330	$700
RAM	16GB (2x 8GB) Crucial Ballistix @ 3200MHz **NEW**	$75	
SSD	512GB Team Group T-Force Cardea Zero Z330 PCIe 3.0 M.2 **NEW**	$54	
HDD	1TB WD Blue 1TB 7200	$40	
OS	Windows 10 Home 64-bit OEM	$32	

Approximate Price: $939 or $1,309

MID-RANGE

WE WERE CONSIDERING going for AMD's slightly cheaper Ryzen 5 5600G chip as our Ryzen 5 5600X CPU is unfortunately not on sale anymore. It's back up to $300, which is sad to see, but this has been fluctuating so much lately, it's worth keeping an eye on it. Because of that, we ended up sticking to the pricer chip due to the faster performance, although you lose out on the integrated graphics. That said, if you do manage to grab one, you won't be disappointed with the 5600G CPU. The Core i7-11700K is now $10 cheaper, however, that still puts it at over $80 more than the AMD mid-range machine.

The motherboards are still suitable for our mid-range builds too. On the AMD rig, the ASUS mobo has gone up slightly by $5, now hitting the $200 mark. This is definitely not as unfortunate as on the Intel side of things, however, as the ASRock Z590M PRO4 for that PC is now an extra $30, bringing it up to $180. At least the prices are a little closer together now.

The mid-range AMD build's RAM has switched over again to a pretty good deal on some Team Vulcan Z CL18 sticks. These have the same 3600MHz speed and 16GB configuration as the previous set, so you won't be losing any performance compared with the previous issue, but the big advantage is that these come in at a respectable price of just $67. We've also decided to keep the Intel version's sticks from last time round, with the Kingston FURY Renegade sticks still providing us with plenty of performance.

The best bet for an SSD in the Intel PC at the moment is Corsair's 500GB Force MP600 PCIe 4.0 drive. Still, at $90, it's a reasonable price, particularly for a 4.0 drive. In the last issue, we shaved off $10 by choosing the Sabrent Rocket SSD, but this time, that has gone up by $20. Seems silly, but we've gone for Samsung's 500GB 980 Pro instead, which is a great reliable SSD at this price. Also, it's no surprise that the GPU situation remains the same—the words 'out of stock' are now permanently etched into our brain.

AMD INGREDIENTS

PART		PRICE	STREET PRICE
Case	Lian Li PC-O11-Dynamic	$150	
PSU	650W Fractal Design Ion Gold	$110	
Mobo	Asus AM4 TUF Gaming X570 -Plus WiFi	$200	
CPU	AMD Ryzen 5 5600X	$300	
Cooler	240mm Cooler Master Masterliquid ML240L RGB	$60	
GPU	Nvidia GeForce RTX 3070 8GB **NO STOCK**	$500	$1,150
RAM	16GB (2x 8GB) Team Vulcan Z CL18 @ 3600MHz **NEW**	$67	
SSD	500GB Samsung 980 Pro NVME M.2 PCIe 4.0 SSD **NEW**	$110	
HDD	1TB WD Blue 1TB 7200	$40	
OS	Windows 10 Home 64-bit OEM	$32	

Approximate Price: $1,569 or $2,219

INTEL INGREDIENTS

PART		PRICE	STREET PRICE
Case	Lian Li PC-O11-Dynamic	$150	
PSU	650W Corsair TX650M 80+ Gold	$95	
Mobo	ASRock Z590M PRO4	$180	
CPU	Intel Core i7-11700K	$400	
Cooler	Enermax Liqmax III 240 RGB	$60	
GPU	AMD Radeon RX 6800 XT 16GB **NO STOCK**	$650	$1,450
RAM	16GB (2x 8GB) Kingston FURY Renegade RGB @ 3600MHz	$95	
SSD	500GB Corsair Force MP600 M.2 PCIe 4.0	$90	
HDD	1TB WD Blue 1TB 7200	$40	
OS	Windows 10 Home 64-bit OEM	$32	

Approximate Price: $1,792 or $2,592

TURBO

FOR BOTH BUILDS, Western Digital's 3TB 5400RPM HDDs have gone from $60 a drive to $70, but it still makes sense to double these up rather than going with a single 6TB HDD at the same RPM. Both turbo PCs have a terabyte of ultra-fast PCIe 4.0 SSDs so it made no sense to opt for a single 6TB faster 7200RPM HDD here as the HDD is purely secondary storage. The price of the Samsung 980 Pro is like a yo-yo at the moment. Thankfully, it has gone down and is on sale again for $177, so we can add it into the AMD rig. This means for this month, we can keep the speeds slightly above the Sabrent model we swapped out, for now at least. Gigabyte's 7000s is out of Intel's system. Currently, this is out of stock, so we have also opted for the Samsung 980 Pro on this side of the fence too.

Both our builds continue with 4000MHz memory this month. The previous G.Skill Ripjaws V RAM have slipped back in due to being $30 below that of the Trident Z Neo's we had in. However, these Trident Z Neo sticks make their way into the Intel machine. Both have nippy speeds of 4000MHz and are in the two 16GB configuration, so we can't complain, considering the prices of these RAM sticks.

Other than the RAM and SSD, nothing changed on the Turbo AMD machine, except a few prices. The motherboard dropped by $20, but the CPU rose by $10 and the HDDs rose by $20. Our Intel machine has a few cost changes, too. Fractal Design's Ion Gold PSUs have gone up by $17, but are still decent value for money. With a seven-year warranty and great build quality, it makes for a sensible deal.

The Intel turbo build sticks with the same MSI MAG Z590 Tomahawk Wi-Fi motherboard, to match its MSI MAG cooler. It's on sale, down to $230 from $270, so with PCIe 4.0 support and great overclocking capabilities to get the most out of our 4000MHz RAM, it's a sensible selection. Both the CPU and MSI MAG cooler have dropped a little in price too, which is always nice to see but, like the AMD build, the HDDs have increased by $20 as a pair. GPUs are still just out of arm's reach and paying almost double still feels criminal to us. It's a tough time for silicon production.

AMD INGREDIENTS

PART		PRICE	STREET PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass	$150	
PSU	750W NZXT C750 80+ Gold	$110	
Mobo	MSI MPG X570 Gaming Edge Wi-Fi	$180	
CPU	AMD Ryzen 7 5800X	$410	
Cooler	Corsair iCUE H150i ELITE CAPELLIX AIO 360mm	$168	
GPU	Nvidia GeForce RTX 3080 10GB **NO STOCK**	$700	$1,650
RAM	32GB (2x 16GB) G.Skill Ripjaws V 32GB @ 4000MHz **NEW**	$140	
SSD	1TB Samsung 980 Pro M.2 PCIe 4.0 SSD **NEW**	$177	
HDD	2x 3TB WD Blue 5400 HDD	$140	
OS	Windows 10 Home 64-bit OEM	$32	

Approximate Price: $2,207 or $3,157

INTEL INGREDIENTS

PART		PRICE	STREET PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass	$150	
PSU	750W Fractal Design Ion Gold	$117	
Mobo	MSI MAG Z590 Tomahawk Wi-Fi	$230	
CPU	Intel Core i9-11900K	$525	
Cooler	MSI MAG CoreLiquid 360R AIO	$109	
GPU	AMD Radeon RX 6900 XT 16GB **NO STOCK**	$999	$1,600
RAM	32GB (2x 16GB) G.Skill Trident Z Neo @ 4000MHz **NEW**	$170	
SSD	1TB Gigabyte Aorus Gen4 7000s M.2 PCIe 4.0	$190	
HDD	2x 3TB WD Blue 5400 HDD	$140	
OS	Windows 10 Home 64-bit OEM	$32	

Approximate Price: $2,662 or $3,261

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